AD-A142 496 RANGE SAFETY SYSTEMS PRE-TEST DIAGNOSTICS(U) TYBRIN CORP FORT WALTON BEACH FL 30 APR 82 ER-TC-SER-82-4 SBI-AD-E800 955 F08635-79-C-0140 1/1

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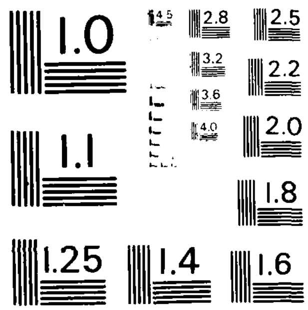

MICROCOPY RESOLUTION TEST CHART
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Engineering Report ER-TC-SER 82-4

Range Safety Systems
Pre-Test Diagnostics

30 April 1982

Prepared for the
Armament Division (AD)

Directorate of Range Safety (SER)

Contract No. FO8635-79-C-0140
Study Task Order SER 82-4

Prepared for
Tybrin Corporation
2018-D Lewis Turner Blvd.
Fort Walton Beach, Florida 32548

by

Science Applications, Inc.
Under Subcontract No. 79-C-0140(4-79)

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FOREWORD

The work in this report was sponsored by the Directorate of Range Safety (SER) under Subcontract 79-C-0140(4-79) of Contract No. F08635-79-C-0140, and is a deliverable item under Study Task Order SER 82-4. The work was monitored by Mr. Ron Knight and Mr. Robert H. Thompson.

ABSTRACT

Effective range safety control of weapon tests on the Eglin range requires that all systems used for control be in a state of operational readiness prior to each mission. Current and future range safety control systems for the Eglin range were investigated in this study, and recommendations were made for pre-test diagnostics. Elements of the real-time range safety control complex considered include tracking, communication, telemetry, computer, display, flight termination, command and control systems and data links.

1.0 INTRODUCTION

1.1 General

Effective range safety control of weapon tests on the Eglin range requires that all systems used for control be in a state of operational readiness prior to each mission. Systems used for real-time range safety control include tracking, communication, telemetry, computer, display, flight termination, command and control systems and data links. Malfunctioning and improperly calibrated systems can cause test cancellations, test delays, or improper flight termination decisions. For example, erroneous estimates of instantaneous impact points (IIPs) caused by improperly calibrated tracking radars are potential sources of incorrect flight termination actions. Earlier studies [1] have shown that IIP predictions from Eglin tracking radars located at the same site have varied by over two miles due to calibration errors.

An early Missile Safety Study [4] for the Eglin range was directed at finding a way to accomodate missile flight testing in the Eglin environment. The study addressed various aspects of a range safety system including pretest diagnostics. In this regard, the study concluded:

> "By utilizing a digital computer as an integral element in overall system checkout it is possible to detect failure modes, perform system calibrations, etc.
>
> It is, therefore, recommended that consideration be given to new/planned ADTC range safety programs with an eye toward the aforementioned facets of

> system checkout. Such systems might include, but would not be limited to, new/proposed instrumentation systems, and specialized equipment systems to be integrated into the range safety environment."

Since the publication of this study, sophisticated systems for range safety control have been integrated i the Eglin range environment. As weapon system performance evolved, the associated testing requirements for these tems have become more demanding. Missiles and other munitions travel faster and further, higher performance drone targets are being introduced into the test environment, and multiple-missile/multiple-drone missions are projected.

In this demanding and rapidly evolving test environment for advanced weapons systems, the need exists for fast, reliable, and automatic pre-test checkout of all systems used for real-time range safety control. As the potential numbers of participating missiles, aircraft, and targets increase so as to create a more realistic test environment, manual, ad hoc or other relatively limited diagnostic procedures become less suitable. Increasing complexity of the tests and the systems involved suggests utilization of computer control for pre-test checkout procedures. Implementation of automatic, optimized, computer-controlled pre-test diagnostics will insure maximum range safety for advanced weapon tests on the Eglin range, not only for current range systems, but also for the new systems to be introduced during the Gulf Test Range (GTR) upgrade.

1.2 Task Objectives and Approach

The objectives of this study were to examine current and future range safety control systems for the Eglin range and to investigate and make recommendations for pre-test diagnostics. The original task statement also called for a review of existing pre-test diagnostic procedures and criteria and identification of existing deficiencies. The study effort was redirected to eliminate these latter tasks because of unavailability of required information caused by competitive sensitivities (not involving Tybrin or SAI) arising from competition of the Eglin O&M contract.

For purposes of this study, range safety control systems were grouped as follows:

- Tracking Systems
- Computer/Display Systems
- Telemetry and Data Handling Systems
- Communications Systems/Data Links
- Command/Control and Flight Termination Systems

Current range systems are described in the following chapters. Also, future systems which are currently being, or soon will be, installed as part of the GTR upgrade are examined. In some cases, the new systems will be substantially different, potentially requiring step changes, rather than a smooth evolution, in diagnostics procedures and criteria. For example, range tracking systems will transition from AN/FPS-16 radars to a

Multilateration System (MLS). Flight Termination Systems (FTS) will utilize MLS digital communication links versus the UHF links current in use. Recommendations are made, as appropriate, in those cases where significant changes in range safety control systems will require further detailed study of pre-test diagnostics.

Section 2.0 summarizes the conclusions and recommendations of this study effort. Section 3.0 contains background material.

Section 4.0 discusses Eglin range tracking systems, current and future. With the new MLS tracking system, all drones, missiles and aircraft will be required to carry MLS transponders. For objects requiring skin tracking, the tracking radars will continue to be used. Calibration of tracking radars is discussed at length, including calibration problems encountered in the past (such as erroneous application of beacon delays and filter bandwidth-related instability problems) and recommendations for the future.

Current computer/display systems are considered in Section 5.0. Existing real-time applications software utilized by the Centralized Control Facility (CCF) can simultaneously process data from only three tracking radars, however, it is planned to upgrade the software to a capability for processing eight radars. Other upgrade plans include the acquisition of up to ten VAX 11/780 computers for real-time processing, with two being currently installed.

Section 6.0 treats telemetry (TM) and data handling systems. The Eglin range upgrade projects use of Airborne Instrumentation Platforms (AIPS) to relay TM data for below line-of-sight missions. The AIPS will provide the opportunity for transmitting TM data through the atmosphere under conditions approximating the mission environment for purposes of pre-test checkout.

Communications systems/data links are addressed in Section 7.0. Microwave systems are being converted from analog to digital links. Checkout of digital links can be accomplished automatically using standardized diagnostic data streams.

Command/control and flight termination systems are discussed in Section 8.0. In the future, drone control will be accomplished using an integrated MLS which will also perform the tracking function. The Multiobject Tracking, Ranging and Control System (MTRACS) is being developed for air-to-surface applications. MTRACS, which is a very sophisticated MLS, will provide tracking and remote control of up to ten land targets, tracking and selective flight termination of at least twelve missiles inflight, and tracking of launch aircraft. The missile FTS for air-to-air applications will probably utilize the MLS flight termination transponder being developed for MTRACS.

A brief summary of the study effort appears in Section 9.0. References are listed in Section 10.0.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were arrived at during this study effort:

- A fast, automatic, reliable and integrated pre-test diagnostic procedure should be accomplished prior to each Eglin mission that requires range safety control. The procedure should check out all range systems utilized in maintaining range safety control, and should be computerized to the maximum feasible extent.
- A study effort should be initiated to determine requirements for pre-test diagnostics of all new instrumentation being introduced into the Eglin range complex as a result of the ongoing GTR upgrade. In many cases, substantial changes in range systems are projected, including eventual utilization of MLS versus tracking radars to obtain TSPI data.
- A slew/calibration pre-test diagnostic routine should be accomplished for the AN/FPS-16 tracking radars prior to each mission requiring range safety control. It has been established that IIPs from adjacent Eglin radars at a common site have differed by over two miles due to calibration

problems. A calibration diagnostic can substantially reduce any systematic or bias errors.

- Tracking of beacon-carrying aircraft should be utilized as a source of external observations required for range radar calibration. The Airborne Instrumentation Platforms (AIPS) projected for use as part of the GTR upgrade will serve as convenient radar targets for calibration. Tracking of AIPS with multiple radars will facilitate the use of inter-radar comparisons as a calibration tool.
- Adaptive filtering techniques should be examined for their potential applicability in pre-test diagnostics for reducing the effects of random errors on tracking radar accuracy. If such methods are determined to be useful in a radar checkout role, procedures for reducing (the variance of) random noise tracking errors during pre-test calibration should be developed.
- A thorough review of the MLS which will be introduced into the Eglin complex should be conducted in advance of its installation. Required pre-test checkout procedures for this sytem should be defined. The number of tracking radars which will remain in service, and their respective roles, should be established.

- It is recommended that a diagnostic software package which will insure operational readiness of CCF computers/display systems be developed. The package may include playback data from previous missions, however, such data should be supplemented by software which will insure that all critical functions are exercised. The pre-test diagnostics software should provide a flexible test procedure with options for reducing checkout time by selecting various checkout modes.
- Diagnostics for the TM system should be an integral part of radar slew/calibration checks and tests of other remote components of the range safety control system. However, procedures which exercise all branches of the TM link including, in the future, transmissions through the atmosphere from the AIPS should be incorporated into TM diagnostics.
- Most, if not all, checkout of communications systems/data links will be accomplished in the process of setting-up and checking-out other elements of the range safety control network. However, it is recommended that checklists be developed to insure that all branches of the network are exercised and checked out. After GTR

upgrade conversion to digital transmission, independent checks of microwave links can be accomplished with diagnostic data streams.

- It is recommended that further study of command/control (C^2) and FTS diagnostics be pursued. Introduction of the new MLS drone control system and MTRACS should be anticipated by developing digital diagnostic routines for pre-test checkout. The MLS transponders will be qualifed for use as a FTS communication link, requiring introduction of digital diagnostic commands and responses for the flight termination system.

3.0 BACKGROUND

In 1971, the Missile Testing Safety Study Committee was formed at Eglin AFB to identify a way to accomodate missile flight testing within the (then) ADTC environment. Since that time, missile testing has become a reality on the Eglin range, and associated risks to facilities and individuals have been minimized by the implementation of a range safety control system. Diagnostic procedures for assuring the operation readiness of this system prior to a mission have been developed. However, these procedures have evolved over a number of years, and are not necessarily integrated, optimal, and/or comprehensive from a systems perspective.

In 1981, the Southeastern Test and Training Area (SETTA) Range Improvement Committee published a range upgrade plan for the GTR. Significant changes in Eglin range instrumentation are projected, many of which will substantially impact the range safety control system.

A requirement exists for fast, automatic and reliable pre-test diagnostics for the existing range safety control system. Also, instrumentation changes projected for the GTR upgrade must be anticipated so that checkout procedures required for future systems will be available when needed.

This study is an evaluation of pre-test diagnostic requirements for the existing range safety control system as well as future systems projected for the GTR upgrade.

4.0 TRACKING SYSTEMS

Pre-test diagnostic procedures and criteria for calibrating Eglin test range tracking radar systems are an important concern of range safety. Improperly calibrated tracking radars are potential causes of incorrect destruct action by the Range Destruct Officer (RDO). These actions could include both unnecessary destruct and/or failure to properly destruct. Since estimates of IIPs obtained from the tracking radars are the primary basis for RDO destruct action, the potential effects of faulty radar calibration are clear. An unnecessary destruct action will destroy valuable resources, while failure to properly destruct may endanger individuals and facilities.

4.1 Radar Instrumentation

The primary tracking radars utilized on the Eglin test ranges are the AN/FPS-16 radars. However, other tracking radars are also utilized, as follows:

- Seven AN/FPS-16 radars (C-Band)
- Three AN/MPS-19 radars (S-Band)
- One AN/FPQ-13 radar (C-Band)

Each tracking radar provides range, azimuth, and elevation data on the object being tracked, and outputs these data to the Universal Data System (UDS) which in-turn interfaces with the Centralized Control Facility (CCF). The seven

AN/FPS-16 radars are located at Sites C-10 (one radar), D-3 (two radars), and A-20 (four radars).

The AN/FPS-16 radars are designed specifically to provide accurate space-position data on airborne objects. They are capable of acquiring, accurately tracking, and providing trajectory data on these objects for real-time use and for other purposes such as post-mission performance evaluation. Specification accuracy for the AN/FPS-16's is 0.1 mil rms in azimuth and elevation and 5 yards rms in range with a signal-to-noise ratio of at least 20 db. However, due to atmospheric and other effects, specification accuracy is not currently attainable under most conditions.

The AN/FPQ-13 radar is a highly-modified AN/FPS-16 which can be calibrated to a much higher level of accuracy than that obtainable with a normal AN/FPS-16 radar. Errors such as droop, skew, nonorthogonality, mislevel, encoder bias, and RF refraction can be greatly reduced. The AN/FPQ-13 uses the "on-axis" or "directed track" concept which applies a new technique for keeping the target centered in the RF beam and for calibrating the angle encoders. The AN/FPQ-13 has the capability for providing real-time data at the radar site in the form of an alpha-numerics display on a TV screen.

The AN/MPS-19 radars are used primarily for drone tracking and control.

The Site A-20 radar building with four AN/FPS-16 radars and the AN/FPQ-13 radar is shown in Figure 4.1. A

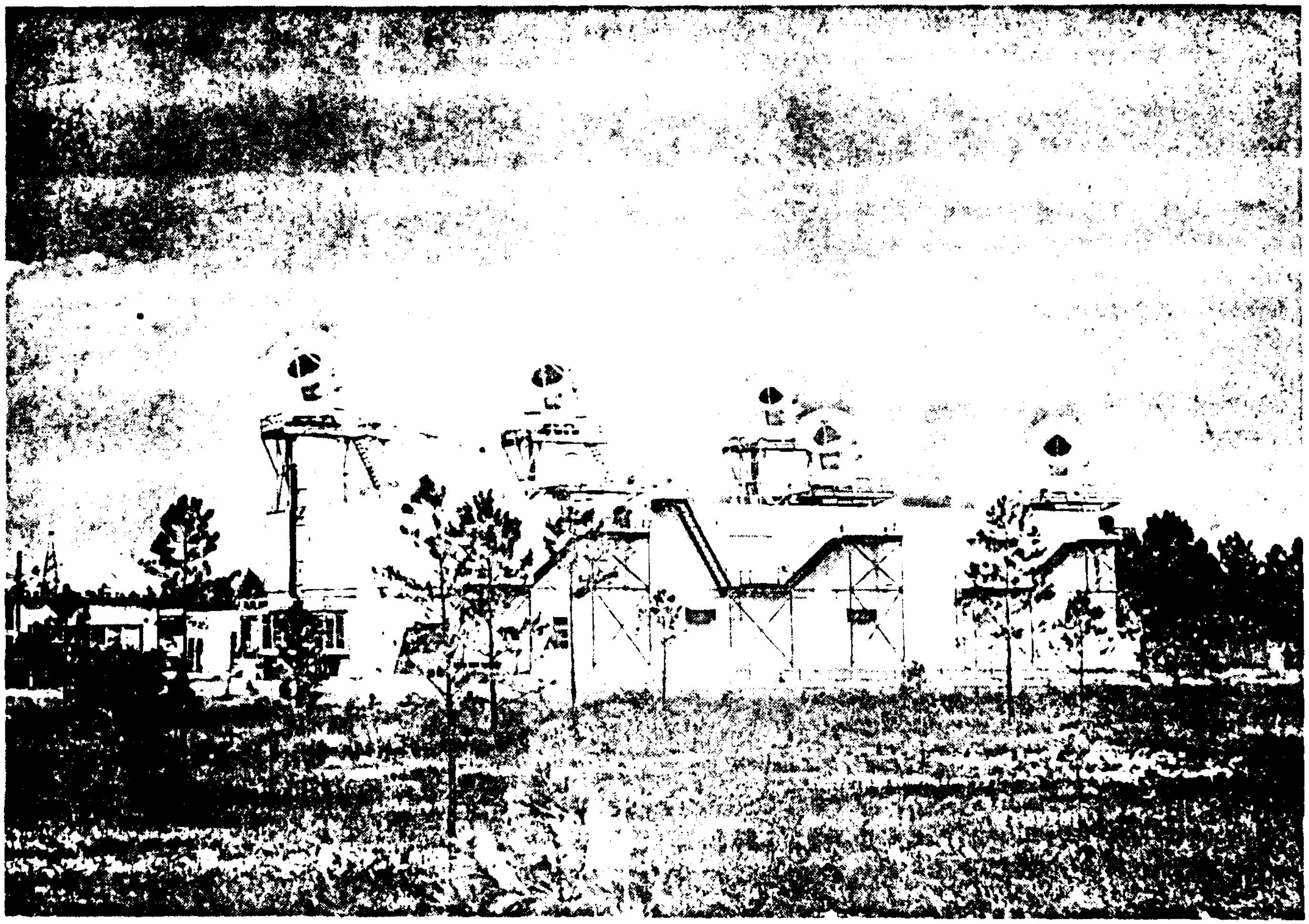


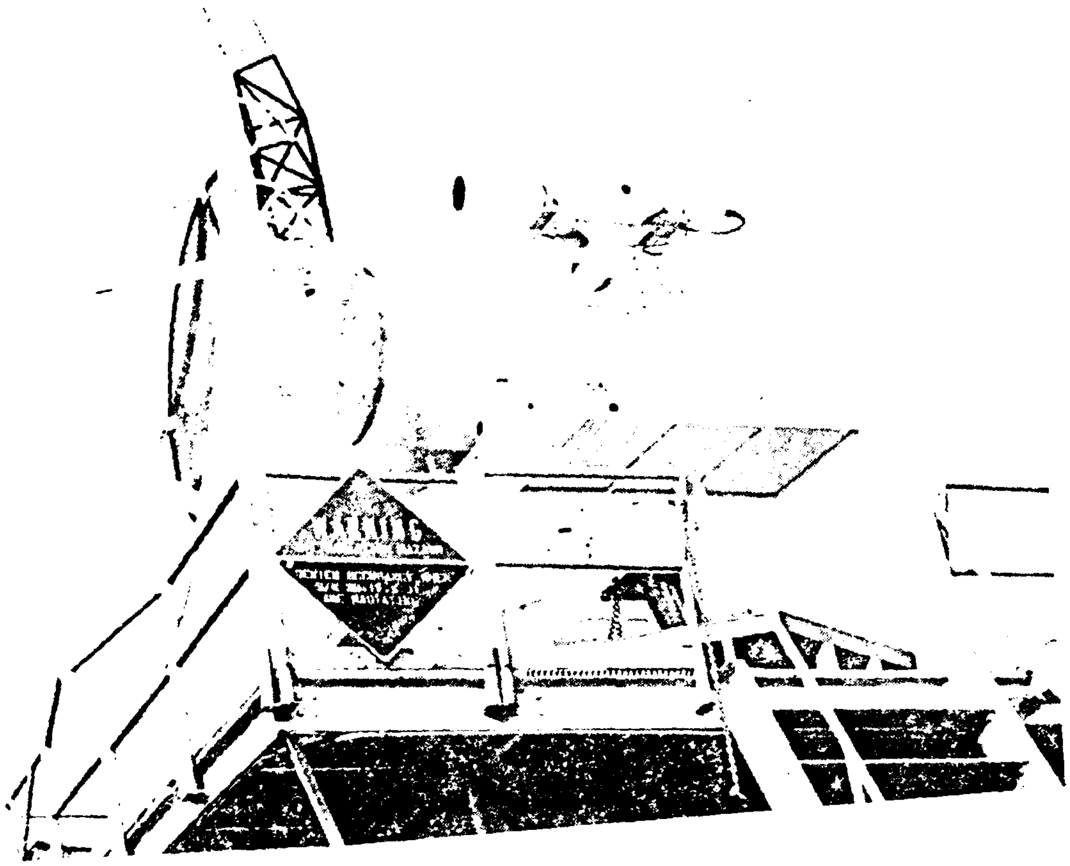
Figure 4.1 Site A-20 radar building

typical AN/FPS-16 installation is shown in Figure 4.2. The characteristics of the AN/FPS-16 are as follows:

- Maximum unambiguous range: 500 nautical miles
- Azimuth: Continuous
- Elevation: -10 to +85 degrees
- Digital output: Up to 20 samples per second
- Dynamic tracking accuracy: Azimuth and elevation, 0.1 to 0.4 mil rms, depending on SNR and elevation angle; slant range, 5 to 6 yards rms.
- Tracking rates: Range, up to 20,000 yd/s on all seven radars; azimuth, up to 40 deg/s; elevation, up to 30 deg/s.
- Antennas: Five radars with 12-foot parabolic; gain, 44.5 decibels; beamwidth, 1.1 deg. Two radars with 16-ft parabolic; gain, 46.5 dB; beamwidth, 0.82 deg.
- Transmitter power: 1 megawatt tunable from 5.4 to 5.9 GHz; pulse repetition frequencies, 160, 320, and 640 pulses per second.
- Pulse width: 0.1, 0.25, 0.5, and 1.0 microseconds.
- Special characteristics: All seven of the AN/FPS-16 radars have parametric amplifiers and five have CCTV trackers with 40/80-inch focal length.

4.2 Tracking System Performance

Earlier studies have shown that substantial discrepancies often exist between IIP predictions made by neighboring radars of similar design. These discrepancies have far exceeded the



Typical Roof Installation of AN/FPS-16
Radar Antenna at Site A-20

Figure 4.2

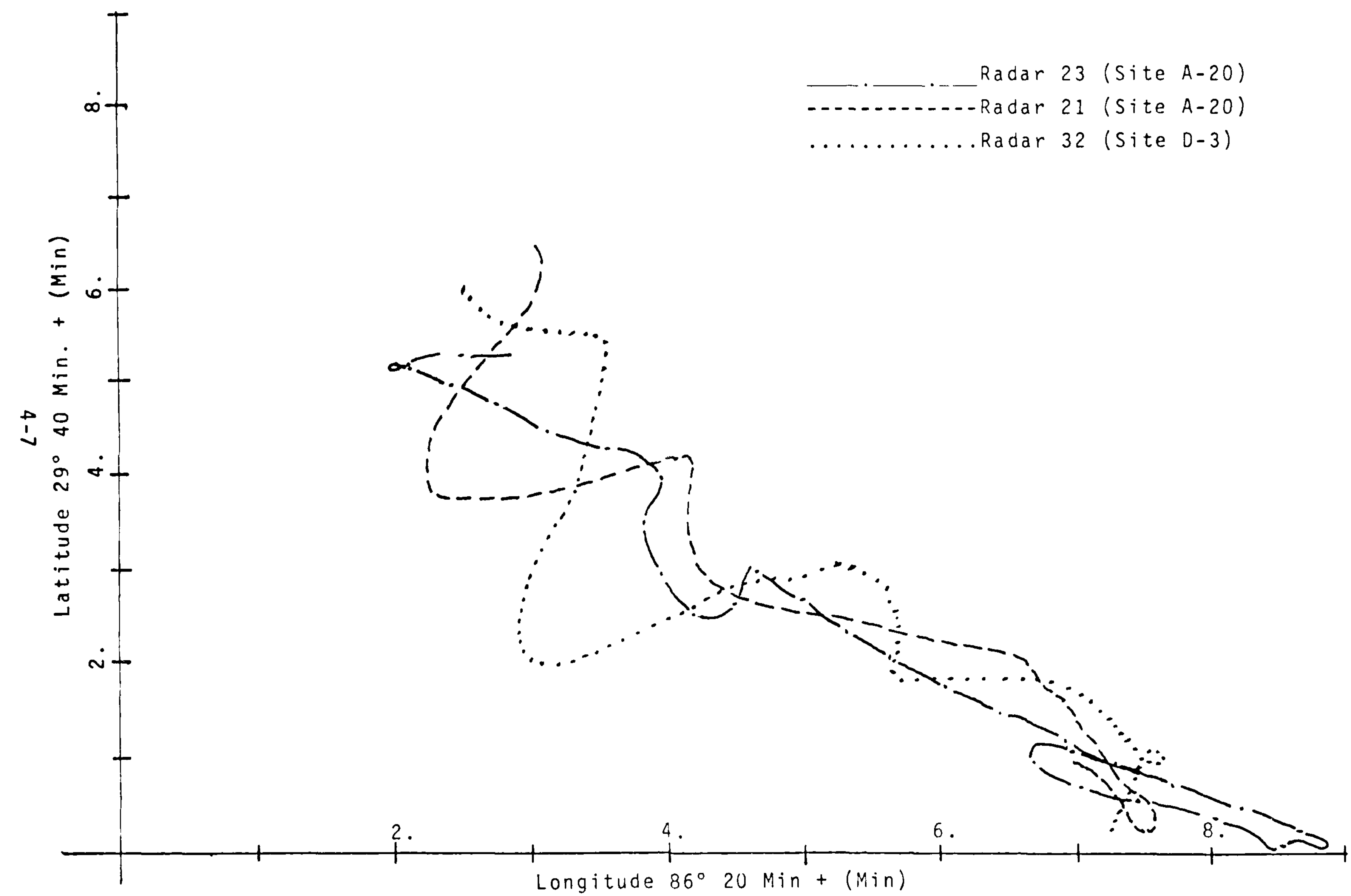
projected accuracies of the radars. As an example, radar data from a mission on the Eglin range has been analyzed [1] for purposes of comparing radar data from simultaneous tracks of the same vehicle (SEEKBAT) by three different AN/FPS-16 tracking radars. Two of the radars were at Site A-20 and one was at Site D-3. All three radars were operating in beacon track.

Plots of the IIP's estimated from the three radar tracks are shown in Figure 4.3. Peak-to-peak variations of more than two minutes of arc (approximately two nautical miles) are apparent in the IIP plots. In particular, IIP differences of as much as two miles exist between the two radars located at Site A-20 within a few feet of each other. Differences in ground range between the three IIP's are plotted versus time in Figure 4.4. Corresponding resultant velocity differences for the three radars are shown in Figure 4.5. It can be seen that the IIP differences were related to velocity differences of more than 100 feet/second.

The low frequency oscillations of relatively large amplitude which were observed in the IIPs and the inter-radar comparisons for this mission have also been observed on other missions. This low frequency noise is illustrated in Figure 4.6 where the first and second derivatives with respect to time of the IIPs from another mission (Bomarc) are illustrated.

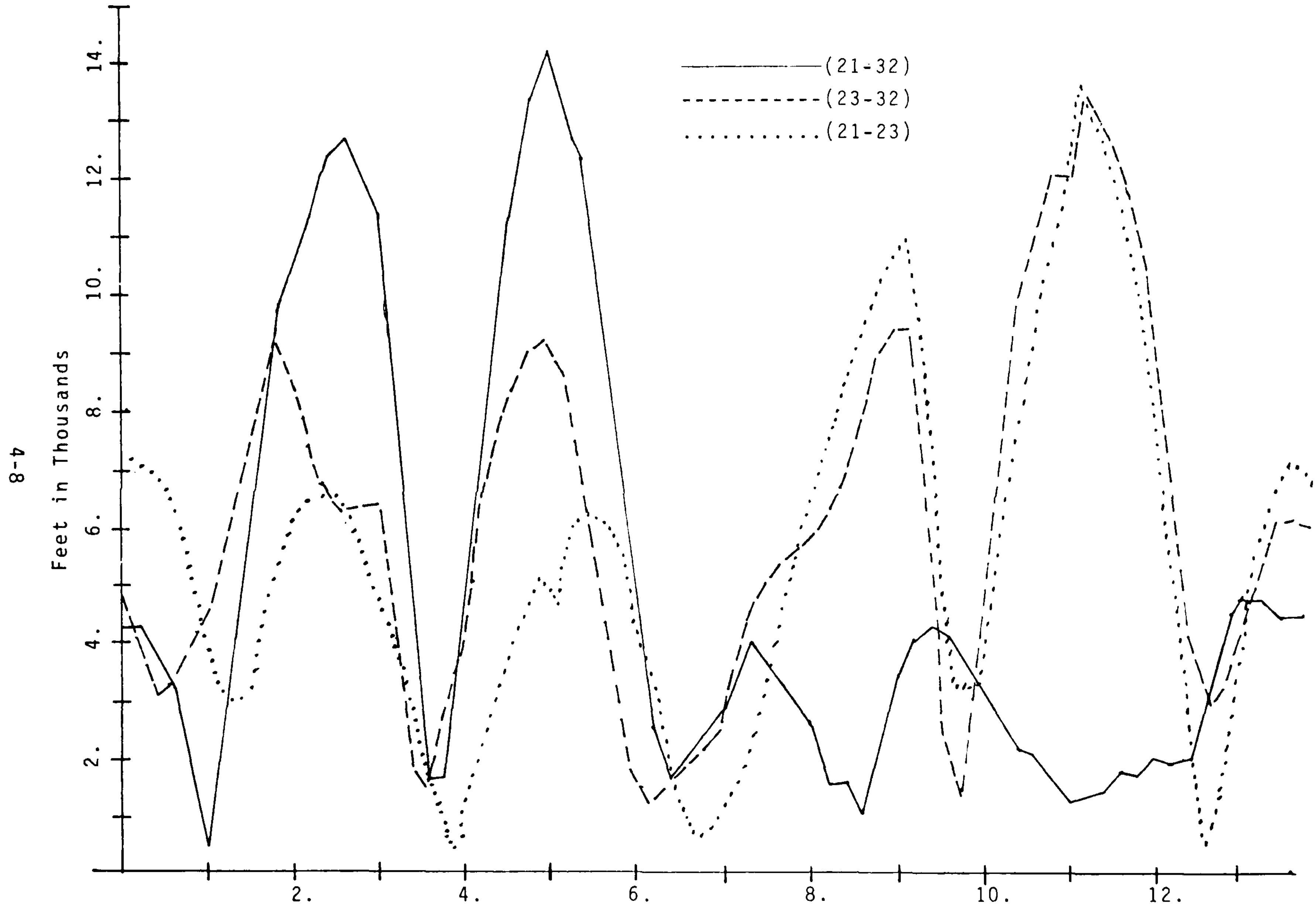
4.2.1 Random and Systematic Errors

Radar errors can be classified as random errors or systematic errors. Random errors refer to the repeatability of a measuring device. If the variation of repeated measurements

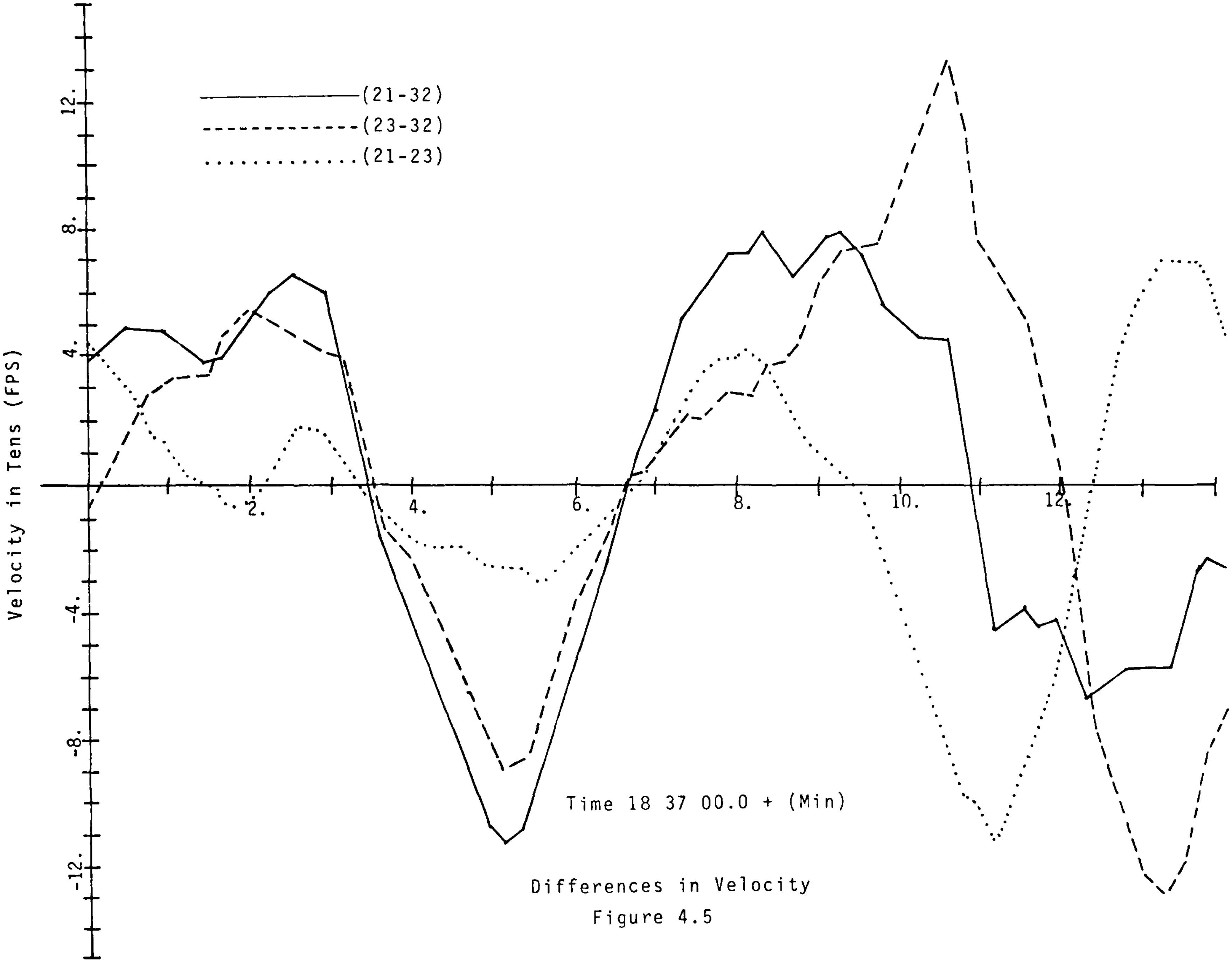


IIP Predictions

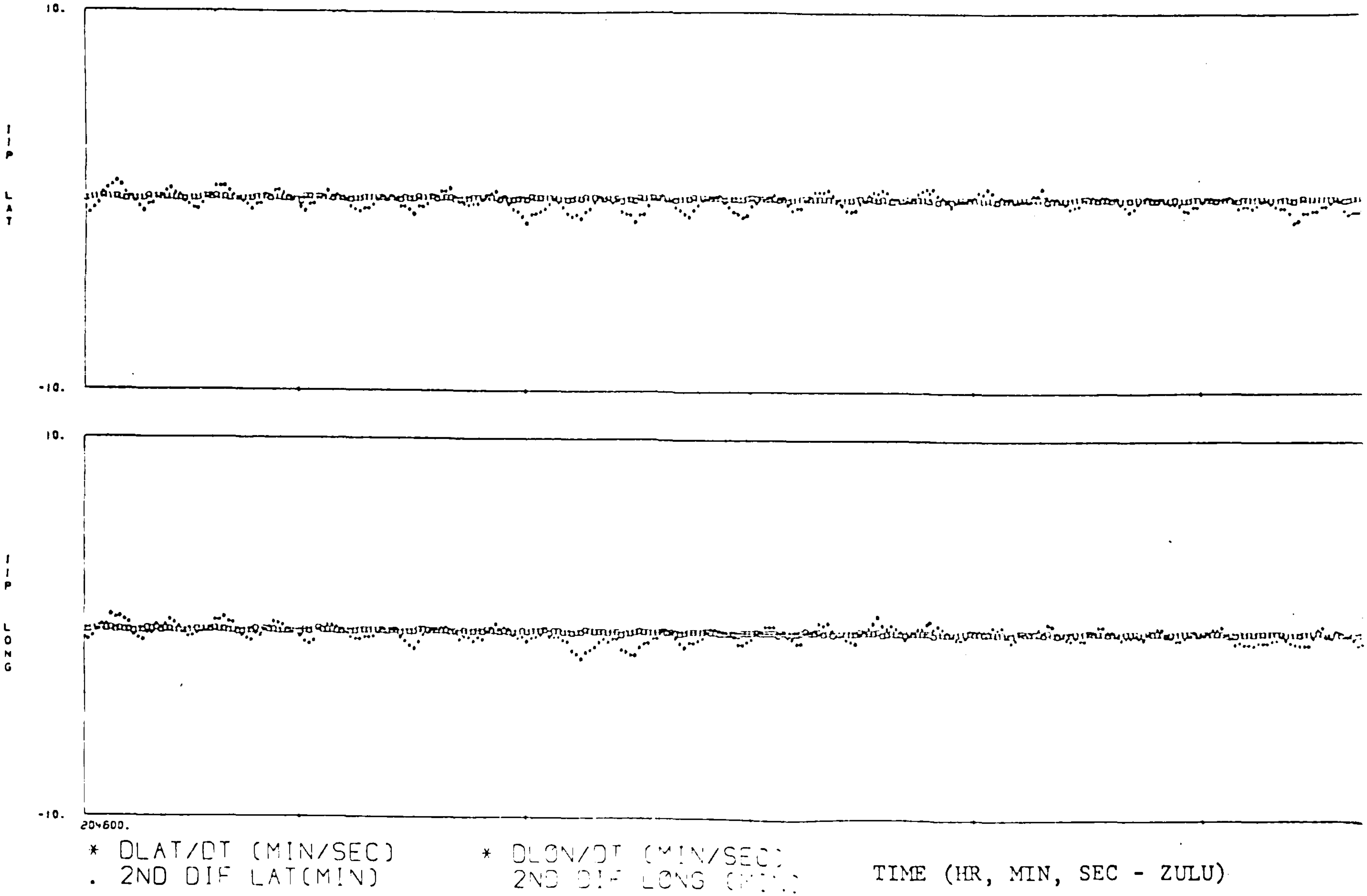
Figure 4.3



Differences in IIP Ground Range Time 18 37 00.0 + (sec)
Figure 4.4



Differences in Velocity
Figure 4.5



IIP Derivatives
Figure 4.6

of the same quantity is small, then the random errors are small and the measuring device is considered precise. A measuring device such as a radar, therefore, can be precise and still not be accurate, since accuracy has to do with closeness to the true value.

Systematic errors are inherent in any instrument used for making physical measurements. Analysis of radar data for systematic errors involves estimating those errors which degrade the data from the standpoint of accuracy (difference from true value). Unlike random errors which are a measure of precision (repeatability), systematic errors are, by their nature, approximate mathematical functions and are therefore predictable. An accurate measuring system or instrument is one which has relatively small systematic errors, and demonstrates a high degree of repeatability. Tables 4.1 and 4.2 list sources of systematic errors.

4.2.2 Skew Errors

An important systematic error is radar skew, which occurs when the RF axis is non-orthogonal to the elevation axis (systematic error 5 in Table 4.2). Skew is to be differentiated from the systematic error commonly referred to as nonorthogonality (systematic error 2 in Table 4.2), as illustrated in Figure 4.7 in that the former is left/right nonorthogonality. Calibration requirements for skew error will now be considered as an example of how the various systematic errors in Tables 4.1 and 4.2 can be reduced.

SOURCES OF RANGE ERRORS

Class of Error	Bias or Systematic	Random
Radar-Dependent Tracking Errors	1. Range Oscillator Frequency 2. Zero Setting the Range Tracker 3. Discriminator Unbalance* 4. Receiver Delay 5. Time Tag Errors 6. Transient Time Errors	1. Range Oscillator Jitter 2. Multipath 3. Servo Loop Noise 4. Variations in Receiver Delay
Target-Dependent Tracking Errors	1. Dynamic Lag 2. Beacon Delay	1. Dynamic Lag Variations 2. Glint** 3. Scintillation or Beacon Modulation*** 4. Beacon Delay Jitter
Propagation Errors	1. Tropospheric Refraction 2. Ionospheric Refraction	1. Variations in Tropospheric and Ionospheric Refraction

* Failure of equal positive and negative range offsets to produce equal and opposite error voltages.

** The apparent displacement of the target position due to changes of the tracking centroid of a complex target.

*** Amplitude modulation due to apparent changes in target size or beacon power level.

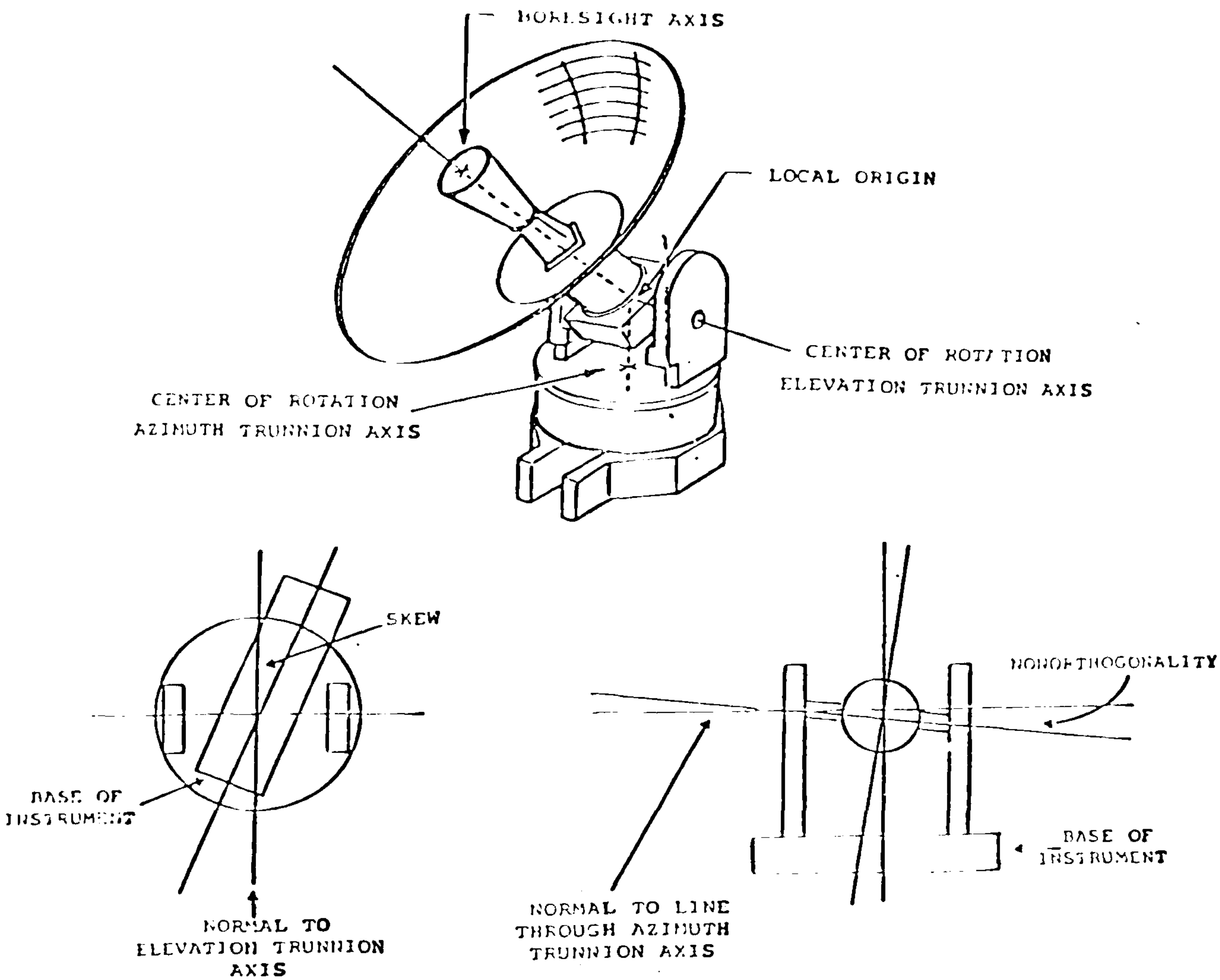
Table 4.1

SOURCES OF ANGLE ERRORS

Class of Error	Bias or Systematic	Random
Radar-Dependent Tracking Errors	1. Pedestal Leveling 2. Orthogonality of Axes 3. Droop (Dish or Feedhorn) 4. Endcoder Zero Set and Nonlinearity 5. RF Misalignment (Skew) 6. RF and IF Axis Shift* 7. Servo Unbalance 8. Time Tag Errors 9. Transient Time Errors	1. Multipath 2. Serve Loop Noise 3. Wind Gusts 4. Bearing Wobble 5. Nonlinearity and Backlast in Gearing
Target-Dependent Tracking Errors	1. Dynamic Lag	1. Glint 2. Scintillation or Beacon Modulation 3. Dynamic Lag Variations
Propagation Errors	1. Tropospheric Refraction 2. Ionospheric Refraction	1. Variations in Tropospheric and Ionospheric Refraction

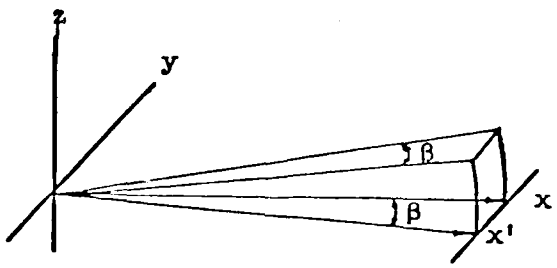
* A change in the lock-on point due to a change in the RF and IF ope ating frequency.

Table 4.2



Skew and Nonorthogonality

Figure 4.7



Radar Skew

Figure 4.8

The skew angle (β) is measured from the orthogonal elevation circle to the skewed elevation circle positive in a clockwise direction, as illustrated in Figure 4.8. Here the y-axis is the elevation shaft and the x-axis is perpendicular to y. At 0° elevation the skew angle is equal to the azimuth correction for skew. In order to correct for this effect, the angles in the skewed system where the measurement occurred must be converted to the equivalent angles in an orthogonal system.

The equation for azimuth (A) and elevation (E) are as follows:

$$A = \tan^{-1}\left(\frac{\tan \beta}{\cos E_M}\right) + A_M \qquad (4.1)$$

$$E = \sin^{-1}(\cos \beta \sin E_M) \qquad (4.2)$$

where A_M and E_M are the misleveled azimuth and elevation, respectively. It is desirable to approximate these equations utilizing the fact that β is a very small angle. For the elevation equation, the approximation that cos β is 1.0, gives:

$$E = E_M \text{ or } E - E_M = 0 \qquad (4.3)$$

Therefore, no correction is needed in elevation. For the azimuth equation:

$$\Delta A = A - A_M = \tan^{-1}\left(\frac{\tan \beta}{\cos E_M}\right) \qquad (4.4)$$

The fact that the small angles β and ΔA are approximately equal to their tangents gives:

$$\Delta A = \beta \sec E_M = \beta \sec E \qquad (4.5)$$

It can be seen that the azimuth correction varies with elevation angle. If skew angle β can be estimated, however, the proper azimuth correction can be determined and applied as a function of elevation.

4.3 Pre-Test Calibration

Systematic errors present in the radar tracks such as those discussed above can typically be substantially reduced by pre-test calibration. For example, estimates of mean bias can be obtained by processing tracks of aircraft, satellites, missiles, or stars using regression analysis computer routines. This mean bias, which is a systematic error, can then be reduced as illustrated in Figures 4.9 and 4.10. A discussion of several candidate calibration techniques follows.

4.3.1 On-Site Direct Error Measurement Techniques

These techniques include:

- Use of surveyed range and boresight towers to determine range bias and RF versus mechnical axis stability. An example of a typical series of boresight errors is shown in Figure 4.11, where the offset from center is the difference between the mechanical and RF axes.
- Use of a Talyvel electronic level to determine nonorthogonality (mislevel) of the azimuth plane with the local vertical.

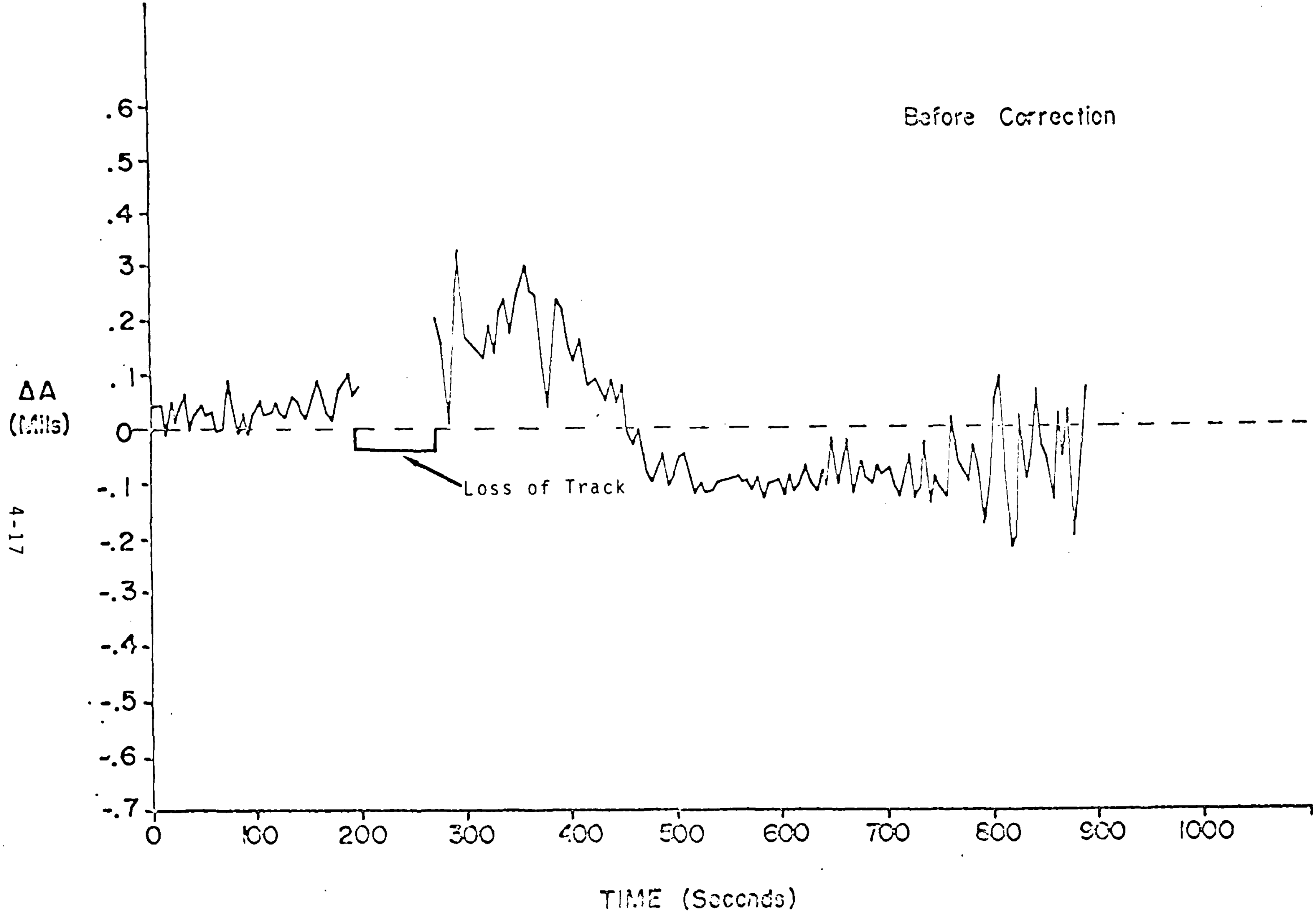


Figure 4.9 Typical Radar Error Residuals Before Calibration

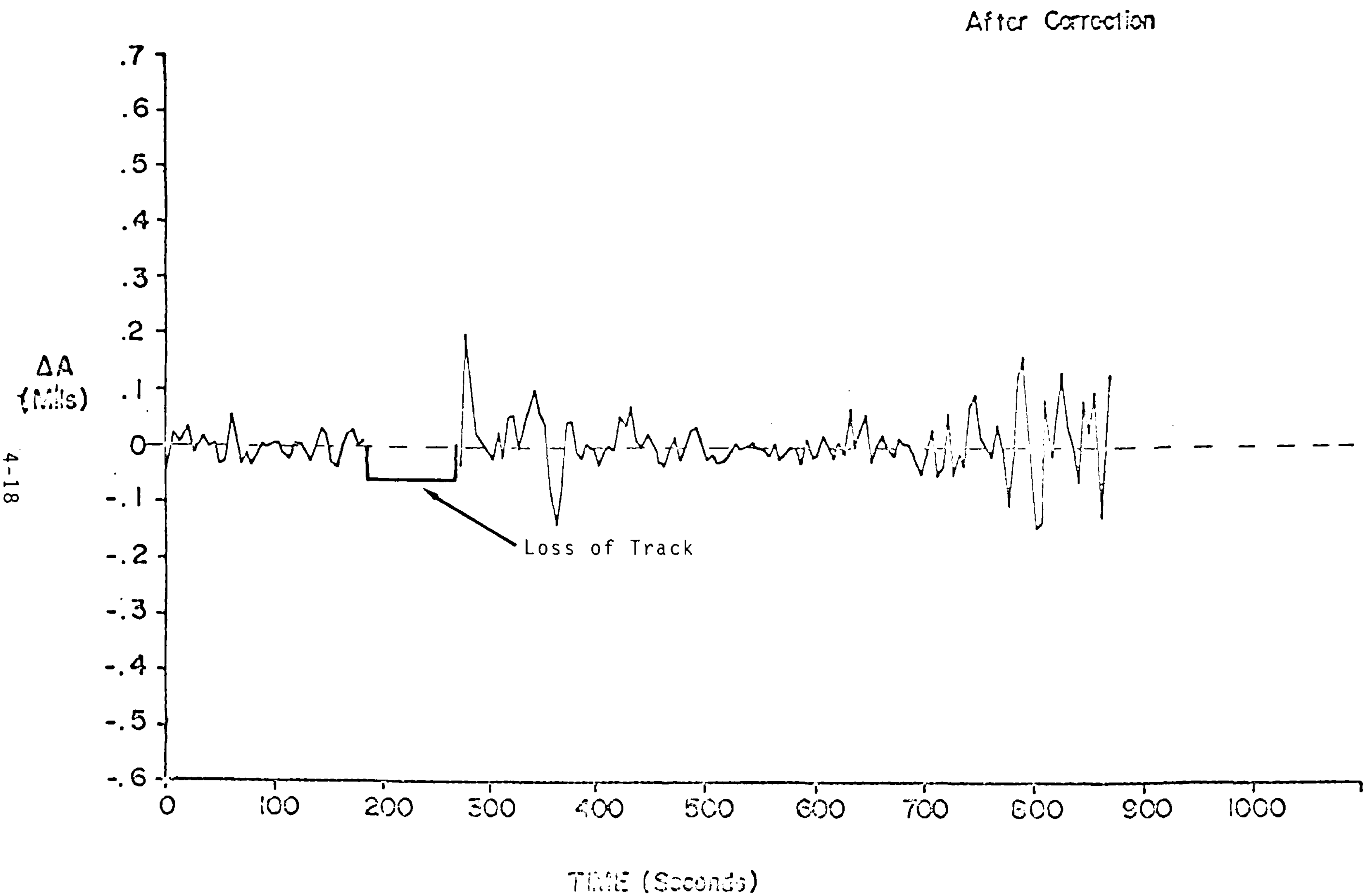
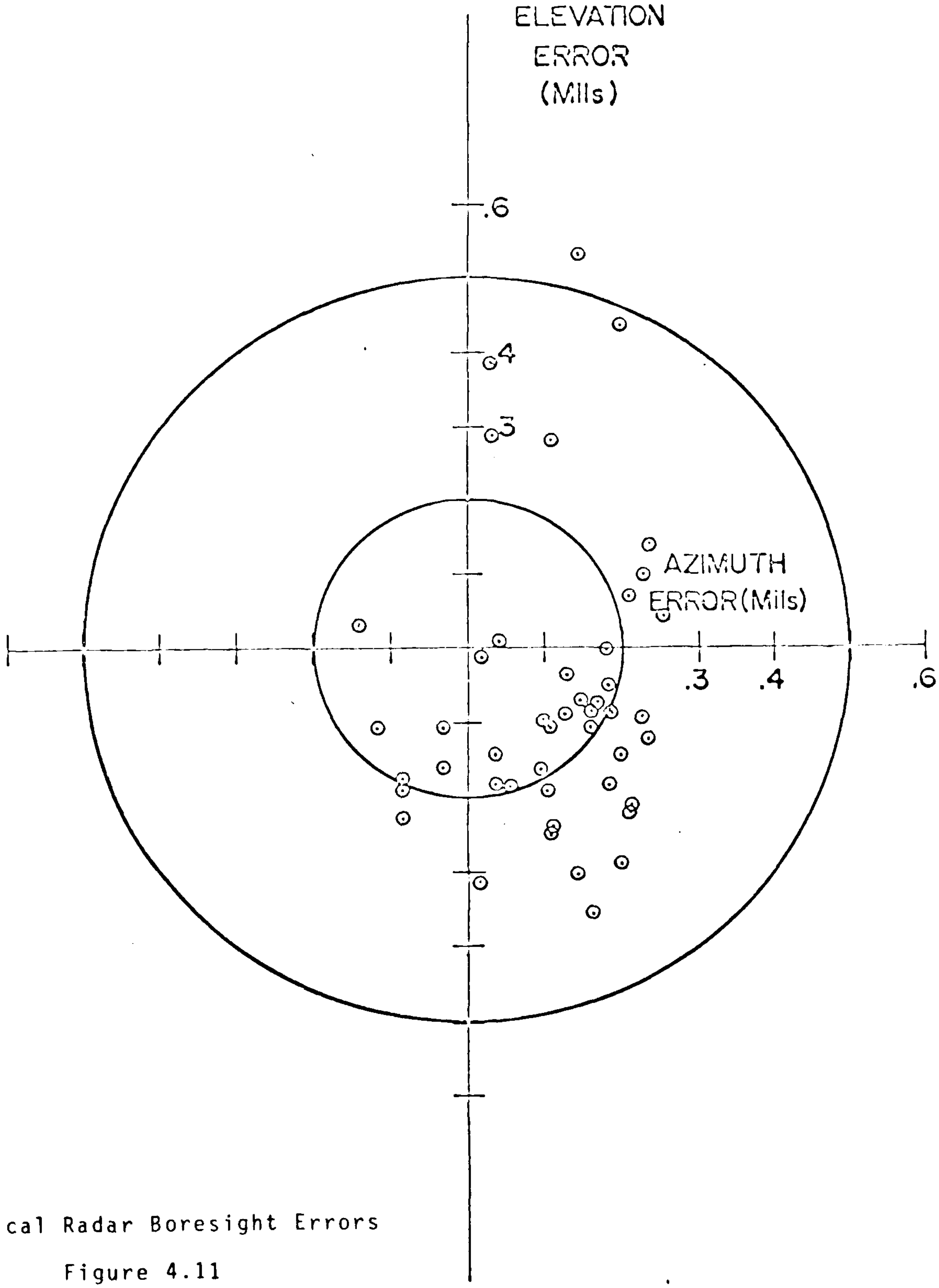


Figure 4.10 Typical Radar Error Residuals After Calibration



Typical Radar Boresight Errors

Figure 4.11

- Use of a precision level sensor to determine nonorthogonality of the elevation shaft and the local vertical.
- Use of mechanical polygons and mirrors to determine encoder nonlinearity.
- Error voltage and signal/noise calibrations.

4.3.1.1 Advantages of On-Site Direct Calibrations

- Can be conducted on a routine basis unless an operational test interferes.
- Requires no special moveable target vehicles.
- Can usually be conducted at low cost.

4.3.1.2 Disadvantages of On-Site Direct Calibrations

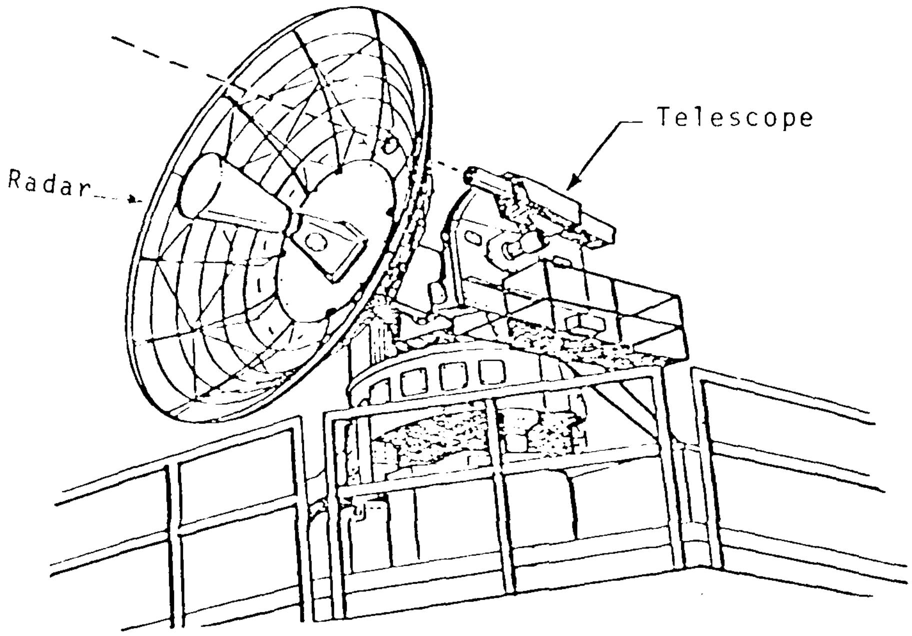
- Due to earth curvature limitations, boresight towers must be located at relatively short ranges from the radars. At short ranges, small errors in target locations propagate into large errors in angle measurements.
- Boresight calibrations are normally conducted at low elevation angles where antenna droop and multipath contaminate the elevation measurements.
- Calibration conditions, especially the lack of dynamics and range of observations, have little resemblance to missile test conditions.
- The calibration devices themselves also require frequent calibration.

4.3.2 Stellar Calibrations

The ephemerides of a large number of visible stars are available in tabular and magnetic tape form. The angular (right ascension and declination) accuracy of the ephemerides is better than one second of arc. By making observations with a telescope (aligned with the radar's mechanical axis as in Figure 4.12) over a wide spectrum of azimuth and elevation angles and processing the observations through a regression analysis computer program, it is possible to estimate most static errors. The accuracy of the calibration can be verified through track of an earth satellite with known orbit, and a further RF-axis/optical-axis correction can then be made if necessary. The use of *radio frequency stars has been proposed for* radar calibration but such calibrations are still in the experimental stage. Radio star calibrations would have the advantage of eliminating the need for an optical telescope and would use RF error voltage measurements in the same manner as on an operational mission.

4.3.2.1 Advantages of Stellar Calibrations

- All combinations of azimuth and elevation measurements can be made on precisely positioned targets.
- Low cost.
- The large variation in observation geometry substantially reduces computational problems by eliminating linear dependence of observational equations, thus allowing easy separation of error terms in a regression analysis computer program.



Stellar Calibration

Figure 4.12

4.3.2.2 Disadvantages of Stellar Calibrations

- The calibrations require substantially cloud-free atmospheric conditions giving rise to a potential scheduling problem.
- A computer is required to interpolate ephemerides look angles and to perform the regression analysis.
- All observations are exo-atmospheric whereas most Eglin missions take place in the troposphere (below 80,000 feet).
- Additional observations other then stellar are needed to resolve the optical/RF-axis differences.

4.3.3 Calibration with Earth Satellite Observations

A large number of satellites and remnants of their launch vehicles orbit the earth. A number of these can be skin tracked by AN/FPS-16's. Others carry radar beacons. Radar observations of satellites with known orbits can be used to determine azimuth, elevation and range errors at a series of time points which can then be processed through a regression analysis program for error estimation. Observations of satellites with poorly known orbits can also be used in determining error estimates if the initial conditions of the orbit at some specified time (epoch) are included in the solution as unknowns. Two-orbit PEGASUS satellite tracks have been used at the Eastern Test Range on a routine basis to monitor radar accuracies.

4.3.3.1 Advantages of Satellite Calibrations

- By applying free-fall (Keplerian) constraints while solving for a satellite's initial state vector, a smooth reference trajectory is provided against which radar data may be differenced. Such differences are especially valuable for analyzing azimuth, elevation and range noise content.
- Several satellite passes and several radars may be included in one solution, resulting in improved error estimates.

4.3.3.2 Disadvantages of Earth Satellite Calibrations

- Only a few passes of objects which AN/FPS-16's can track are normally available during a 24-hour period.
- Special satellite acquisition aids, including an on-site computer, are usually necessary.
- Lack of geometry variation in satellite passes reduces the ultimate resolution of the error estimation process.
- Tracking of satellites carrying radar beacons usually must be scheduled far ahead of the desired tracking period.
- The smooth trajectories of satellites do not closely resemble the powered flight trajectories important to Eglin range safety, and are also exo-atmospheric.

Errors related to powered flight in the atmosphere with beacon track may not be sufficiently related to satellite tracking errors.

4.3.4 Calibration with Aircraft Observations

An alternative to stellar and earth satellite calibration which appears particularly attractive for Eglin operations is that of calibrating the radars with data gathered from beacon-carrying aircraft flights. Specially designed flight plans (e.g., figure-8 shaped, racetrack shaped, helical) would be desirable. However, preliminary analysis indicates that tracks of a pre-mission surveillance aircraft following normal flight plans could be used to estimate most of the radar systematic error immediately prior to a mission. Theodolite tracks could be used in calibrations involving special aircraft flights, but could not be used in near real-time solutions. Near real-time solutions would require processing of data from two or more radars with a regression program.

4.3.4.1 Advantages of Aircraft Calibrations

- Tracking takes place under conditions resembling the operational mission. A beacon and antenna similar to those that will be used in the test vehicle could be installed on the aircraft.
- If calibration is done with pre-mission surveillance aircraft, no special planning or expense is involved other than computer scheduling.

- For special aircraft calibration runs, geometry and dynamics may be varied as desired to allow better resolution in estimating errors. Theodolite data could be used to improve such estimates.

4.3.4.2 Disadvantages of Aircraft Calibrations

- The aircraft beacon and antenna may have different characteristics than the beacon and antenna on the test vehicle.
- At least two radars at different sites tracking the same target simultaneously are required for error estimation.

4.3.5 Best Estimate of Trajectory (BET) Calibration

Another calibration technique involves use of the operational mission data for calibration. If more than one radar tracks the same target, an overdetermined situation exists in which the additional degrees of freedom may be used to estimate radar biases in addition to the trajectory coordinates.

4.3.5.1 Advantages of BET Calibration

- Radar systematic error estimates are free by-products of the BET solutions.
- Estimated radar errors are those which have affected an actual mission. Possibility of drift since the last calibration is minimized.
- No special pre-mission aircraft runs are required.
- No scheduling problem.

4.3.5.2 Disadvantages of BET Calibration

- Is only available post-flight; any errors which might have caused safety problems during the mission will be determined after the fact.
- Geometry and dynamics are limited to those of the mission. This may limit estimation of errors.

4.3.6 Calibration with Hybrid Solutions

It is possible, through the use of a regression program, to combine various or all of the aforementioned techniques in one comprehensive radar error estimate. This would be an optimum approach to the radar calibration problem. In such a solution, it would be assumed that certain terms, such as mislevel, droop and nonorthogonality, remain constant over all tracking periods whereas other terms, such as zero-set, collimation and refraction, drift from one period of track to the next.

4.3.6.1 Advantages of Hybrid Solution

- Would give a better error estimate (smaller variance) than any one of the individual calibration techniques.
- The error estimate could be recursively updated as new data became available. Old calibration data would receive less and less weight.

4.3.6.2 Disadvantages of Hybrid Solution

- Time consuming.
- Requires use of large computer.

4.4 Future Systems

4.4.1 Multilateration System

The Gulf Test Range (GTR) upgrade which is currently underway will involve a transition to a Multilateration System (MLS) as the primary TSPI system for the range. The MLS will consist of a network of ground interrogator stations which make multiple measurements of distance to a transponder aboard each aircraft, drone, or missile. Position information is computed from these measurements. No high-gain tracking antennas or remote manned tracking sites are necessary. Improved low altitude line-of-sight coverage is possible since the ground interrogators can be mounted on higher towers than can tracking radars. Also, the MLS system can be expanded out to sea on existing towers and by use of range support aircraft.

Only cooperative targets equipped with a transponder can be tracked by the MLS system. No skin track or surveillance capability will be available. Since there will be a continuing need for precision tracking of non-cooperative objects, some or all of the existing AN/FPS-16's will have to be retained.

4.4.2 Airborne Instrumentation Platform

Also included in the GTR upgrade are plans for acquisition of two types of aircraft to be utilized as Airborne Instrumentation Platforms (AIPS). A multi-mission aircraft such as the Beech C-12 (maritime version) will perform the functions of sea

surveillance, telemetry relay, UHF radio relay, and visual search for light aircraft. A single-mission aircraft (initially a T-33 and later a low-cost all-weather aircraft such as a Bonanza or Cessna 210-P) will be used to carry multilateration transponders to provide expanded MLS coverage geometry and vertical-axis augmentation.

The AIPS will provide a convenient mechanism for tracking radar calibration as discussed in Sections 4.3.4 and 4.5.2, as well as independent position data through its Inertial Navigation System (INS).

4.5 Radar Diagnostics

Pre-test radar slew and calibration checks should be conducted for all tracking radars to be used on any given mission. The slew diagnostic ultimately verifies the process of measuring, transmitting and receiving real-time data. The calibration procedure estimates and reduces the systematic or bias errors present in the radar data.

4.5.1 Slew Check

Rapid variation of tracking radar orientation in azimuth and elevation is referred to as slewing. For purposes of pre-test diagnostics, range slew should also be considered. Typically, azimuth, elevation and range are incremented and then decremented at constant rates according to a pre-established profile. Second differences in azimuth, elevation and range are then computed and checked. Since slews are at constant rates, the second differences should be zero; if they are not, slew errors are indicated (note that data link errors, as discussed in Section 6.0, are also possible).

4.5.2 Radar Calibration

Various radar calibration techniques typically involve the following steps:

- Establishment of an error model.
- Controlled tracking of an accurately known target.
- Determination of error model constants and reduction of error.

A correct error model is required if accurate tracks are to be produced. Unwanted disturbances, if allowed to contaminate the trackina data, translate into errors. These errors must be modeled and estimated so that they can be removed. The equations which describe these errors are referred to as the error model.

Tracking an accurately known target provides the external observational capability required to estimate bias errors. Although random errors can be reduced by filtering which requires no external standard, direct observations are mandatory for reduction of systematic or bias errors. As discussed in Section 4.2.1, filtering can provide more precise tracks; however, bias removal is required to obtain more accurate tracks. As discussed in Section 4.3, tracks of stars, satellites, or aircraft can be utilized in bias reduction. In the case of an aircraft, either the position of the aircraft must be known independently and accurately, or tracks from two or more radars must be available as discussed in Sections 4.3.4 and 4.3.5.

The AIPS (see Section 4.4.2) which will be acquired as part of the GTR upgrade can provide the external standard required for tracking system calibration.

Having defined an error model and obtained tracks of a known target, error model coefficients can then be estimated. Typically, some form of regression analysis is used to estimate model coefficients.

Error models for calibrating the AN/FPS-16 radars used on the Eglin range are discussed in [1]. In general, it is desirable to formulate a model which will provide adequate calibration accuracy and require estimation of a minimum number of coefficients. The number of model coefficients will be related to the number of error sources considered sufficiently significant to be included in the model (see Tables 4.1 and 4.2). An example of the bias reduction which can be realized through calibration is illustrated in Figures 4.9 and 4.10.

5.0 COMPUTER/DISPLAY SYSTEMS

Control and analysis required for real-time test support of Eglin range missions is provided by the CCF. The computer/display systems which support the CCF are central to the effective conduct of range safety mission support. Effective pre-test diagnostics for other systems supporting range safety mission control is ultimately based on the assumption that the computer/display systems are operating properly. The diagnostic software which resides in the real-time computer system insures the operational readiness of the computer/display systems as well as other hardware systems required for effective range safety control.

5.1 Instrumentation and Facilities

All real-time mission analysis and control within the Directorate of Computer Sciences is provided by the CCF located within the Building 380 complex at Eglin The multi-purpose computers which support the CCF have access to most range resources (radars, telemetry, and airborne units). Through specialized computer hardware/software configurations, mission data are processed to provide real-time test analysis and control information.

The CCF computers support the entire Eglin scientific community but may be utilized as scheduled, multi-interfaced, real-time computers. The management, operation, system and application software development and real-time analysis to support CCF are provided by the Directorate of Computer Sciences.

The major CCF data resources are (see Figure 5.1):

- Data Collection Systems
- Radars
- Telemetry
- Video

Building 380 houses the main analysis and control center for conduct of most real-time missions. The main center is divided into two areas. Area 1 contains two real-time analysis consoles and two real-time control consoles. Area 2 contains two real-time analysis and four real-time control consoles. In addition to the display consoles in the main analysis and control center, there are auxiliary CRT displays available in Building 380 for data quality monitoring and augmentation to the main center displays.

5.1.1 Real-Time Analysis Console

The real-time analysis consoles (see Figure 5.2) are used for presentation of radar and/or telemetry data under positive computer program control. This information can be maps, graphs, air-to-air displays, time histories or other special purpose displays derived from various data sources or appropriate simulation models. Keyboards associated with each CRT display provide operator interaction with the real-time software in setting up and controlling mission phases, entering parameters or selecting displays. The real-time analysis console component list is as follows:

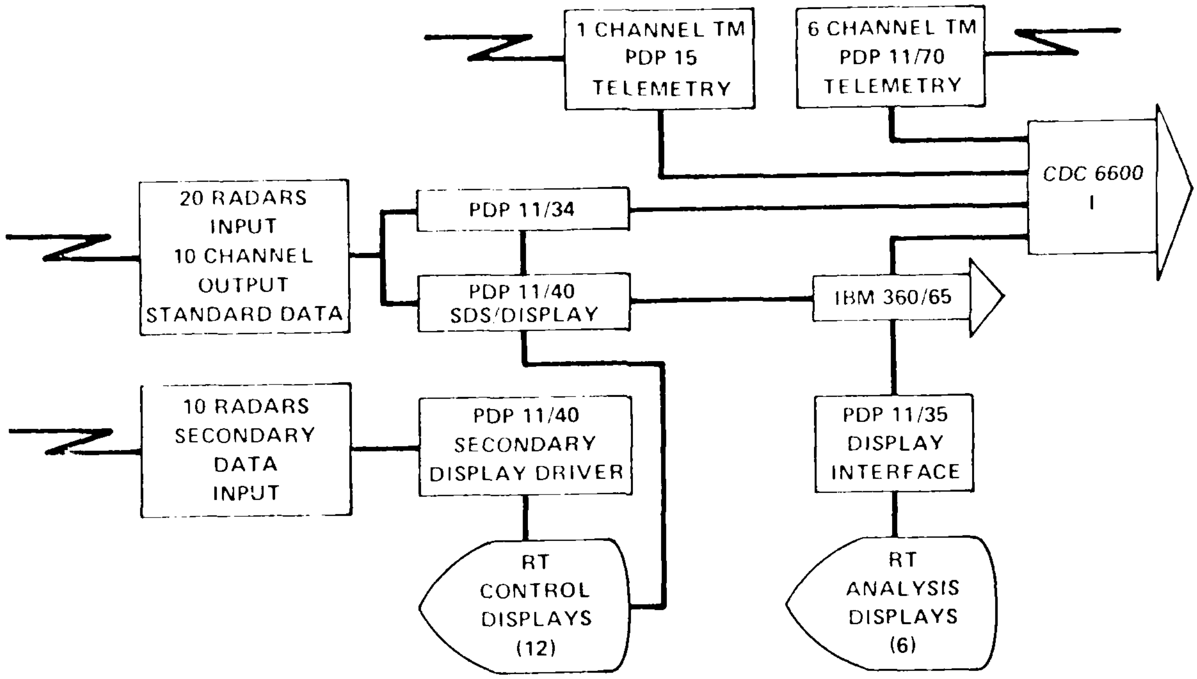


Figure 5.1 CCF real time configuration

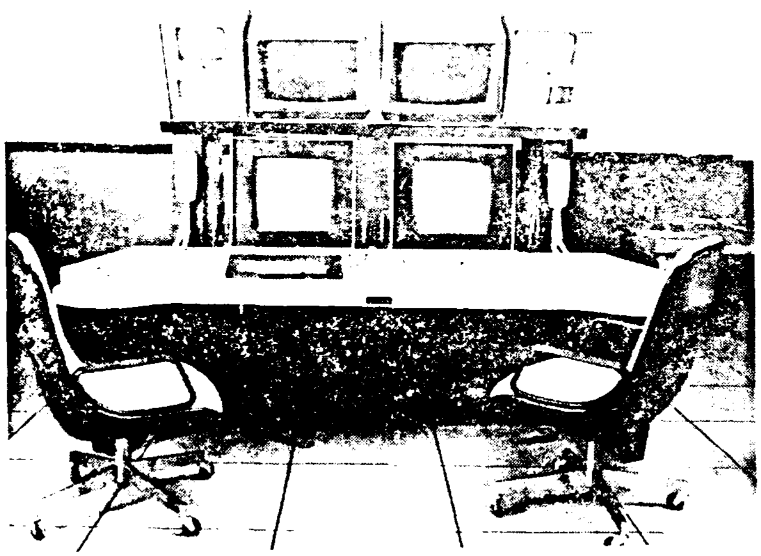


Figure 5.2 Real time analysis console

- Vector General Graphic Display System. Two high speed refresh, interactive graphic CRTs with 3-D capability. Interface via keyboard, function button, light pen devices and hard copy are available to the users.
- Tektronix 4014 Display System. Two storage type CRTs augmented by Motorola 6800 microprocessors provide additional capabilities. Keyboard, function button and joystick interface devices and hard copy output unit are provided.
- Burroughs Plasma Display. Two display units are available for digital presentations.
- TV Monitors. Two units (525 lines).
- Communication Panels. Two units with five fixed and seven selectable positions, plus intercom positions included in each panel. Headsets and telephone instruments are also available.
- Status/Control/Flight Termination Panels. Their configuration is similar to those currently in use at various remote sites.

Alphanumeric and function button keyboards are provided on each console for interface with application programs. When units are not required, most can be disconnected and placed out of the user's way. Each function keyboard has 16 buttons, and overlays are available to indicate the particular function

of each button during each test phase. Joystick and light pen devices will soon be added to the system.

The status/control/flight termination panels allow Range Safety to select the destruct mode, command source, and antenna for each mission and lock out possible interference from remote locations. Flight termination provides the necessary switches to sequence through a destruct cycle. This capability makes the CCF the control site for Range Safety functions. The status/control allows CCF users to originate and display status signals between central and remote locations. These are general purpose switches that can be specifically configured for a particular mission.

5.1.2 Mission Control Console

The mission control consoles (see Figure 5.3) are used for positive aircraft control via primary or secondary radar data. The M&O contractor mission director and aircraft controller control the mission range resources and aircraft under the overall direction of the Test Wing Test Director. The mission control consoles are driven by the IBM 360/65 computer using primary radar data from the Eglin Standard Data System (SDS). In the event of commercial power failure, the consoles switch to auxiliary power from a 30-kV portable generator. At the switch, software on PDP-11 computers takes control and provides displays utilizing secondary radar data to enable the controller to maintain positive control.

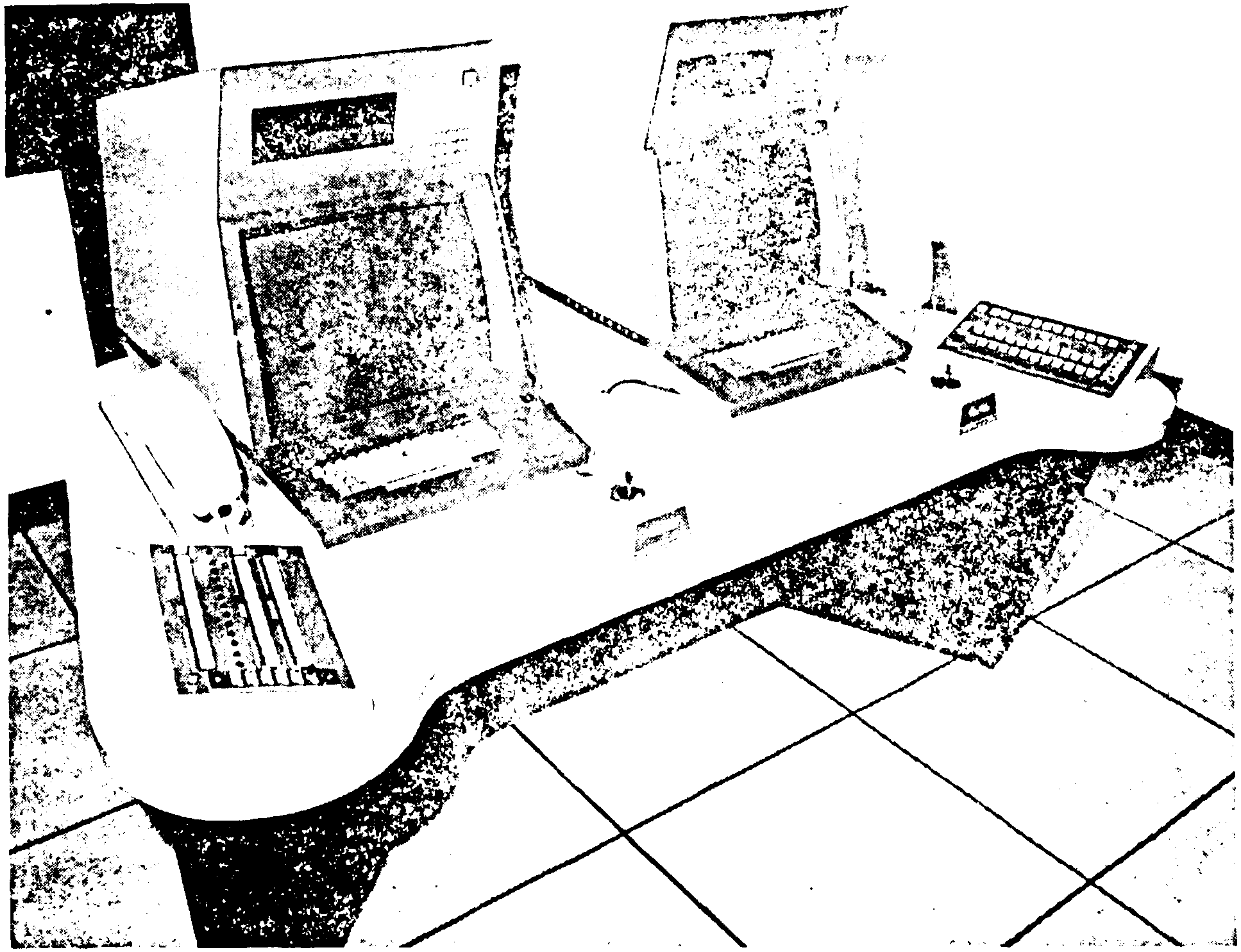


Figure 5.3 Real-time control console

The mission control console component descriptions are as follows:

- Tektronix 4014 Display Systems. Two storage type CRTs are augmented by Motorola 6800 microprocessors. Keyboard, function button and joystick interface devices and hard copy units are also available.
- Burroughs Plasma Display. Two digital display units available for parameter, status and operational information presentations.
- Communication Panels. Two units with fixed, selectable and intercom positions are included in each panel. Headsets and telephone instruments are also available.

5.1.3 Computer Systems

There are three main computer systems and three telemetry systems which, individually or in combination, provide the CCF with real-time analysis and control information. The existing multipurpose system, CDC 6600, IBM 360, Telemag (PDP-15), and the Secondary Data Display System (SDDS) (PDP 11) computers have sufficient hardware/software capability to support a wide variety of real-time requirements.

The CDC 6600 computer is used to execute the larger and more complex real-time analysis software. This system has access to all data sources. Real-time telemetry and radar data

are usually collected, merged, and analyzed on this computer. A special operating system controls multiple real-time application programs and communicates with the other support computers, ultimately driving any selected combination of CCF resources.

The IBM 360 computer and its operating system are designed to run multiple real-time jobs with interrupt handling of many external devices and data systems. A special operating system controls all real-time programs and tasks within the IBM 360. This system also drives the real-time control consoles. The CDC 6600 computer utilizes the IBM 360 to update data on the analysis consoles and transmit and receive data via the SMS.

The Telemag computers can perform digitizing, pre-processing, software data compression, data selection, format conversion, sampling and editing of telemetry data in real-time with data displayed or retransmitted to the CDC 6600 computer for further processing. The PDP-15 computer can process up to two telemetry streams depending on the data rates. The PDP-11/70 systems adds an additional six stream telemetry capability with hardware compressors to improve transfer rates.

The SDDS is driven by PDP-11 minicomputers and receives secondary data directly from the radar sites. It is totally independent of the other computers, displays and data sources. A 30-kV generator has been installed to operate the SDDS (displays and minicomputer), voice communication systems, and signal and control (destruct) systems during critical missions. This system

can transmit display data to the real-time analysis and/or control consoles. On keyboard command, the SDDS will provide mission data to any requesting console via Tektronix 4014 CRTs. The application software draws maps, computes various parameters and displays aircraft present position graphically and parameters in digital form on CRTs. The system will perform two CCF functions - primary system back and aircraft control. The SDDS is intended to provide the CCF with a computer system backup capability so that missions in progress can be continued or terminated in the event of a primary computer or display system failure.

5.1.4 Real-Time Application Software

The CCF system, as described above, is an environment of data systems, computers and displays which requires application software. The development of specifically tailored application programs provides the means for user interaction with the CCF environment. Two important broad categories of real-time software capability include range safety and operational readiness.

The consolidated safety program handles the safety aspects of real-time mission support. The programs furnish the Range Safety Officer (RSO) with information which will maximize RSO effectiveness in protecting personnel and public and private property. The four main safety control categories at Eglin are launch control, release control, flight control, and fire control.

These four categories are covered by the following range safety programs:

- Vacuum Trajectory Instantaneous Impact Prediction (VTIIP). The VTIIP option provides positive launch control during launch and deployment of all surface-to-air vehicles such as the Bomarc. The variety of information furnished to the RSO includes real-time present position in ground plane and vertical plane, IIPs, radar status and quality, and automatic source selection. Graphic and alphanumeric display is provided on the CCF analysis console. Destruct actions are initiated through the flight termination panels on the CCF consoles.
- Ballistic Drag Instantaneous Impact Prediction (BDIIP). The BDIIP option provides positive release control for all unpowered air-to-ground weapons, such as ballistic and guided bombs. Various information supplied to the RSO enables safety criteria to be met. Display information consists of present position, speed, altitude and heading of the launch aircraft, and present position and drag and wind-corrected ballistic impact point of the weapon throughout its trajectory. These data are provided in real-time through alphanumeric and graphic CRT displays.

- Fire Control System (FCS). Positive fire and positive flight controls are provided by the FCS option. The FCS program is a real-time program developed to support missions involving live firing of air-to-air or ground-to-air rockets/missiles against manned aircraft. The program provides the RSO with positive, safe CLEAR-TO-FIRE indications as well as providing control and vectoring information for achieving design test conditions. Graphic and alphanumeric data are displayed on the CCF analysis console.

The operational readiness programs are utilized to verify the status of hardware systems, such as radar and telemetry, which provide data to the real-time application programs.

5.2 Future Systems

Two VAX 11/780 computers are currently being installed in the CCF, and will replace the IBM 360 computer. Four additional VAX 11/780 systems will be acquired over the next several years. The GTR upgrade plan calls for the acquisition of an additional four VAX systems (total of 10), plus large-screen color displays; however, detailed planning is yet to be accomplished.

5.3 Diagnostics

A comprehensive automatic checkout of the entire CCF real-time computer/display hardware and software systems should be accomplished immediately prior to each mission requiring range safety control. A diagnostic software package

which will insure operational readiness of CCF systems is recommended. This package could include playback data from previous missions; however, such data should be supplemented by software which will insure that all critical functions of the computer/display system are exercised.

The time urgency often associated with mission scheduling is an important factor impacting the problem of pre-test computer/display system diagnostics. It will normally be necessary to complete system checkout in minimal time and, in some cases, scheduling demands may reduce the time for system diagnostics to the extent where a comprehensive system test is not feasible. This supports the requirement for an automated flexible test procedure with options for reducing checkout time by selecting various checkout modes. Further study of this problem area is recommended.

It should be noted that a pre-test diagnostics procedure which exercises the display systems will also serve to "checkout" test monitors who utilize the displays. In particular, any participating personnel who do not have previous experience with the CCF displays will be provided an opportunity for familiarization with the equipment and its operation.

6.0 TELEMETRY AND DATA HANDLING SYSTEMS

6.1 Telemetry Systems

The Eglin range telemetry (TM) complex operates from several strategically located sites separated by distances of up to 125 miles. Automatic, manual and fixed widebeam antenna systems with associated real-time data processing equipment are located at Sites B-4A, D-3, Building 130 (Penthouse), the Mobile TM Van and Site A-15A. All facilities are capable of receiving data transmitted in the 1435 to 1535 and 2200 to 2300 MHz frequency bands.

Most of the telemetry equipment is housed at Telemetry Site B-4A (Figure 6.1) and at downrange Site D-3. Both sites are equipped with three 16-foot high-gain autotrack parabolic receiving antennas. In addition, an omnidirectional antenna is available at each of these sites for close-in mission support. A considerable amount of ancillary equipment is interconnected with the receiving equipment to provide a complete and independent capability within each telemetry building. Each basic tracking system includes a 16-foot parabolic reflector and a dual-element feed (preamp). Each system has a capability for the passive automatic tracking of RF signals.

The tracking systems have high pointing accuracy (0.8 degrees rms) and good dynamic capabilities (to 30 degrees per second). Right hand or left hand circular polarization switching

Figure 6.1 Telemetry Test Site B-4A

is provided to select the strongest polarization sense. The system will select the strongest signal on which to maintain space track when more than one signal is engaged. Operational modes available include: automatic acquisition, automatic tracking, automatic reacquisition, and slave and manual antenna positioning. Horizontal and circular scan submodes may be used in target acquisition. All data received may be recorded (pre- or postdetection) in composite form on magnetic tape for post-mission reduction, presentation and analysis.

Azimuth and elevation coverage in continuous one-way clockwise or counter-clockwise rotation is limited to 720 degrees and 900 degrees while elevation tracking limits are -5 to +85 degrees. Missions requiring continuous azimuth tracking in either rotational direction around Sites B-4A, D-3 and the Mobile Telemetry System must schedule a second antenna system to allow unwrap of the first antenna when 720 or 900 degrees has been exceeded. Tracking profiles directly over the sites must be avoided, or loss of signal may be experienced.

A real-time data reduction and presentation capability of FM/FM, pulse amplitude modulation (PAM), and pulse code modulation (PCM) data are provided by means of discriminators, decommutators, and magnetic tape and direct-writing recorders. Typically at Site B-4A, 42 channels of FM subcarrier discrimination and 64 channels of PAM or PDM decommutation are available. Other sites have a reduced capability as a result of support requirements. Proportional bandwidth channels 1 through 21 and A through

H are installed at all sites. Programming has been accomplished for FM channels 1 through 25. Magnetic tape recording capabilities have been newly upgraded at all sites to provide 2 MHz direct to 500 kHz FM recording and playback. Major facility direct-writing recorders provide 70 channels of limited evaluation data stripout at Site B-4A, 62 channels at Site D-3, and 18 channels in the TM van.

All telemetry sites have some capability of receiving, recording, multiplexing and demultiplexing telemetry data as completely independent stations. However, a means of transmitting telemetry data by microwave uprange and downrange, and controlling or selecting the site at which to present the data, is provided. This serves to better utilize the existing site capabilities, ties the stations together as one integral telemetry system, and presents the real-time test and telemetry control data between the telemetry sites and the CCF. A TM data multiplex of PAN/PDM, PCM can be transmitted from the 900 kHz predetected site receiver output. All major fixed telemetry facilities are capable of supporting secure telemetry.

6.1.1 Telemetry Facilities

6.1.1.1 Site B-4A

The Ground Telemetry Facility at B-4A is located in and adjacent to Building 5203 approximately 20 miles northwest of Eglin Air Force Base. The facility supports test missions

utilizing telemetry on and over the land areas and the northern portion of the Gulf of Mexico and is the prime telemetry facility supporting missions in these areas. Telemetry data are received from the test items, recorded and processed in real-time or post-time on-site. Telemetry data can also be transmitted in real-time by microwave to the CCF. The checkout facility for ground-launched rocket probes at Site A-15A on Santa Rose Island provides B-4A with telemetry data during prelaunch and initial liftoff. B-4A supports rocket launch missions through liftoff, receives and retransmits telemetry data to Site A-15A during flight, and provides real-time telemetry data to the Drone Control Center at Site A-3 for use by the ground controllers. A mobile telemetry van based at B-4A is available to supply supplemental coverage as required. Site B-4A can also process data received by microwave from the D-3 telemetry antennas when mission profiles would prevent use of the B-4A antennas.

6.1.1.2 Site D-3

This Telemetry Subsystem is part of the Test Site D-3 System Complex and is located at Cape San Blas, Florida, approximately 125 miles east/southeast of Fort Walton Beach, Florida. D-3 is a general-purpose site used to collect TSPI on airborne objects and to provide the necessary facilities for mission control, range safety, data recording and transmission, telemetry reception, UHF command guidance, data display, and communications for mission support. The site instrumentation has the capability

for recording the data on site, transmitting it in real-time to the CCF, relaying it to other range sites, and receiving or transmitting acquisition data. The Site D-3 Telemetry Subsystem is the prime site for supporting downrange, over-water missions. This site can receive and process TM data in real-time, or transmit the TM data via microwave to Mission Control or Site B-4A for real-time display.

6.1.1.3 Mobile Telemetry System(MTS)

The MTS is a telemetry facility comprised of two specially-equipped vehicles that may be utilized independently of other range TM facilities. The purpose of the MTS is to provide mission support over the northern portion of the Gulf of Mexico and over the land range areas in instances where local, close-in, and/or on-the-deck maneuvers may shield certain aspects of the transmitter from the base TM station.

6.1.1.4 Flight Line Telemetry Facility

The Flight Line Telemetry Facility is located in the Penthouse on the roof of Building 130, an aircraft hanger located on Eglin AFB property. The facility functions as a self-contained receiving and processing system and interfaces with Site B-4A through a retransmission system.

Ground test and pre-flight checkout support consists of the reception of telemetry signals from aircraft or weapons systems located inside the hanger or on adjacent runways, taxiways and apron areas. Two low-gain, remotely-controlled antennas

and a helix antenna provide reception of signals from runways, taxiways and initial mission segments prior to transfer to the prime telemetry facility at B-4A.

6.1.1.5 Site A-15A

The missile/target telemetry launch facility at Site A-15A is located on Santa Rosa Island in the main blockhouse. The TM capability provides for real-time pre-flight checkout of missiles and targets equipped with standard telemetry packages and for the retransmission of these data to Site B-4A for limited evaluation displays.

The purpose of the Site A-15A missile/target launch facility subsystem is to provide on-site support for the missiles launched from there. Data parameters are made available to the missile launch officer during pre-flight to certify launch readiness. After launch, telemetry data are available for the RSO to determine if the missile/target is operating within safe boundaries.

6.2 Data Handling Systems

All operational tracking radars on the Eglin ranges have data systems associated with them. These data handling systems provide the means for collecting electronic tracking data within the instrumentation complex and delivering it in a convenient and useful format. The two major methods of accomplishing this task are digital magnetic tape recording and real-time or computer on-line processing. Two important systems in

these areas are the Universal Data System (UDS) and the Standard Data System (SDS). The data systems are installed at various test sites and are integrated to provide considerable flexibility for supporting tests of all types. Data management, processing and computational services are performed by the Computer Sciences Laboratory (Data Central) in Building 380. Mission data flow to and in the CCF is depicted in Figure 6.2.

6.2.1 Universal Data System (UDS)

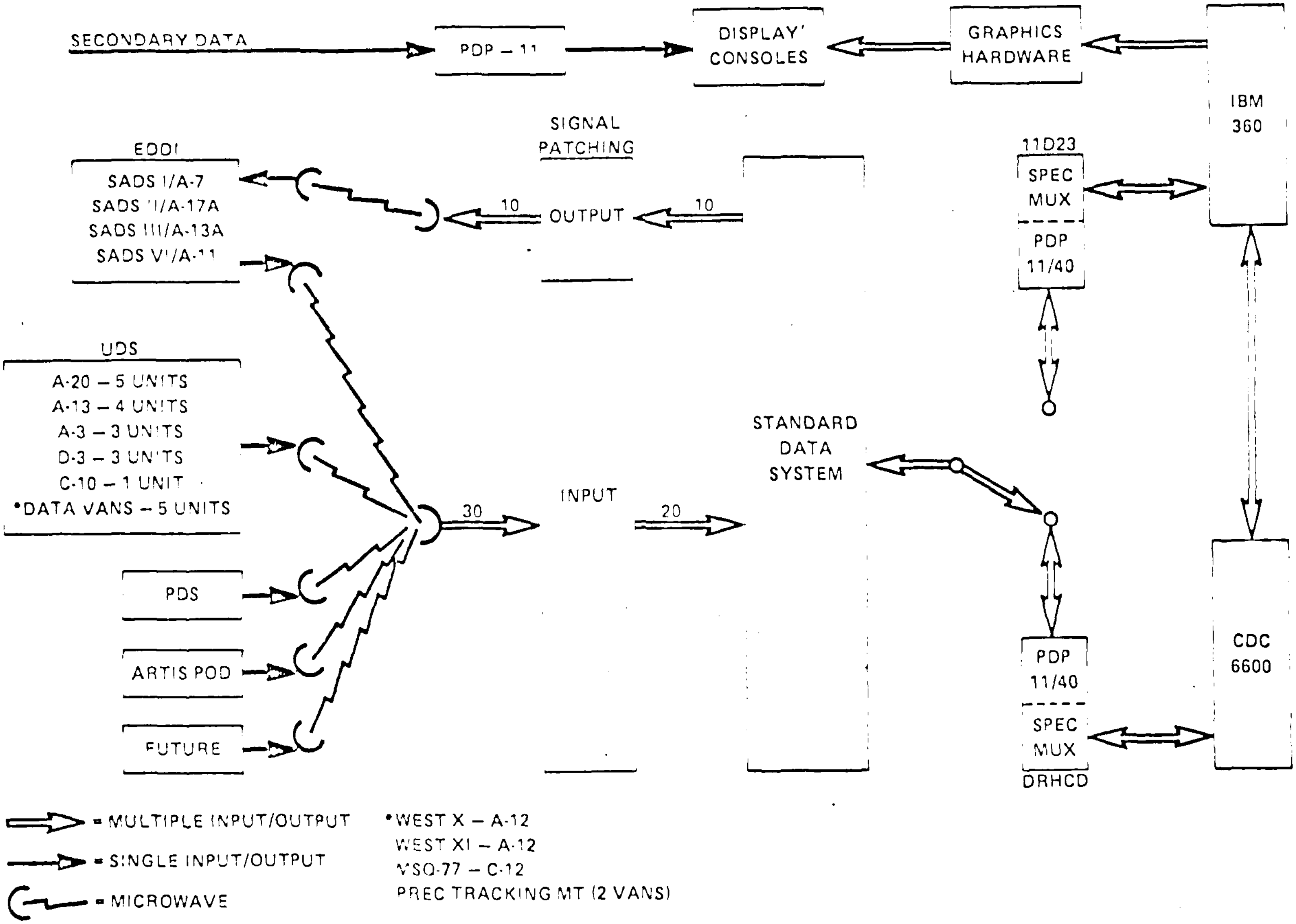
The UDS is a new data system recently installed throughout the Eglin range to replace obsolete equipment. Twenty-one of these units are installed at radar sites, providing a range-wide standard data format and the same serial data transmission scheme for all units. The UDS interfaces with the CCF via the SDS. The UDS performs four basic functions; radar/data interface, data controller/display, digital tape recorder and data transmission. A functional block diagram is shown in Figure 6.3.

6.2.1.1 Radar/Data Interface

The UDS provides a highly flexible interface. It utilizes a standard data format and interfaces with various radars throughout the Eglin Range. The UDS accepts digital data (range and angle), discrete radar modes (auto, manual, skin/beacon, etc), and up to four analog voltages which are digitized to eight bits each.

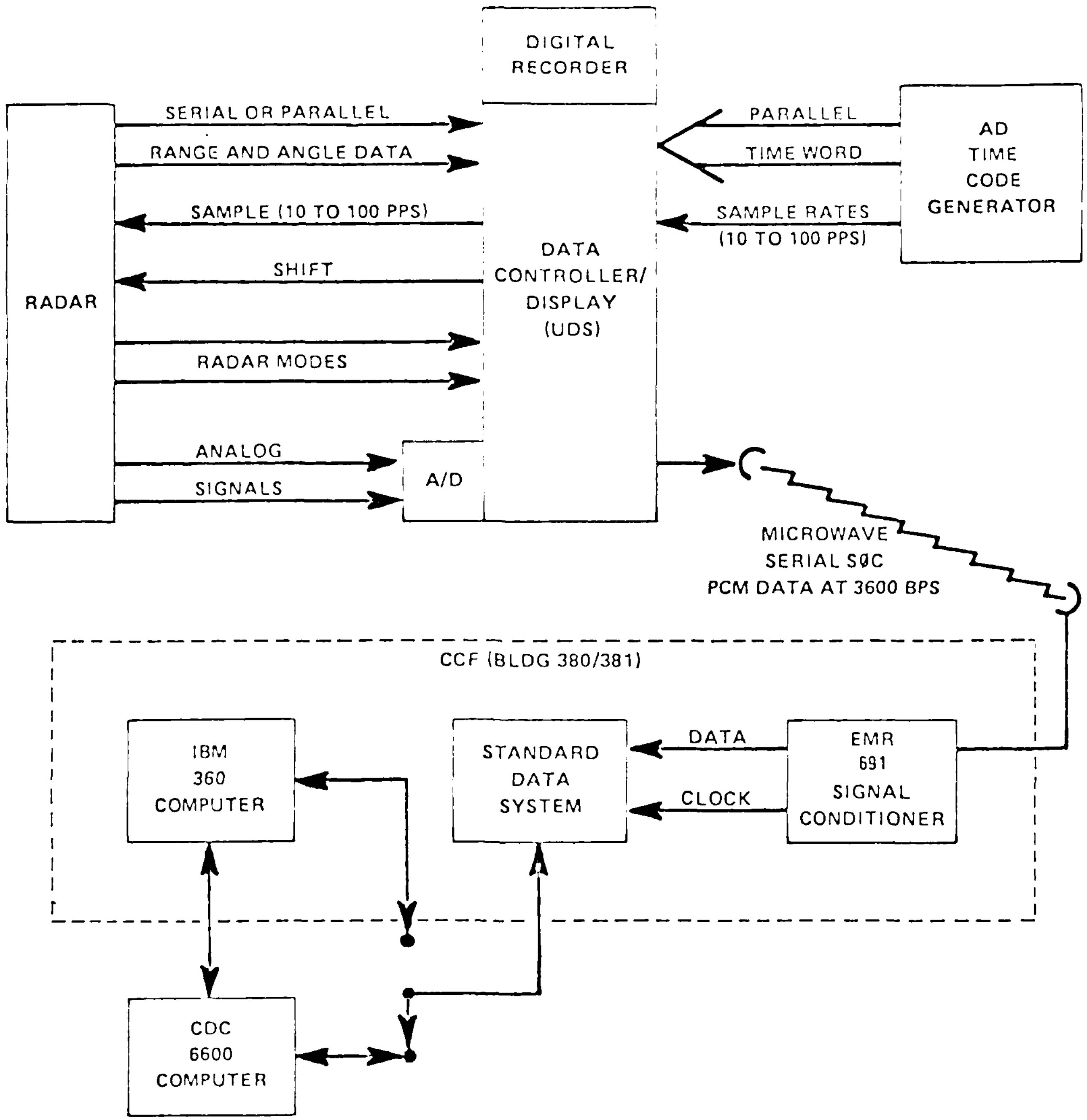
6.2.1.2 Data Contoller/Display

The data controller is the heart of the data system. It accepts data from the radar/data interface, provides system



Centralized Control Facility Data Flow

Figure 6.2



Universal Data System Functional Block Diagram
Figure 6.3

timing and control, formats and displays data, provides for auxiliary data and automatic self-test features, and outputs data for transmission via microwave to the CCF. It also interfaces with the digital recorder and the time code generator.

6.2.1.3 Digital Tape Recorder

All data are recorded on magnetic tape in Industry Standard format. A nine-track, 1,600-BPI machine, using phase encode (PE) techniques is used. Read-after-write electronics are provided to detect data dropouts. Record size provides for six data samples (240 bytes) recorded in each record. Playback mode provides playback of recorded data for transmission to the CCF.

6.2.1.4 Data Transmission

Data is transmitted at the rate of 10 samples per second. Serial PCM data is clocked out to the range microwave system at 3,600 bits per second. The sync word (32 bits) is the standard IRIG PCM frame SYNC pattern located in the first 31 bits with a "0" dummy loaded in the 32nd bit slot.

6.2.2 Standard Data System (SDS)

The SDS (Figures 6.2 and 6.3) is located in the CCF and serves as a large buffer interface system between the many range sites and the computer/display complex in the CCF. The SDS has 20 identical input channels and 10 output channels. Each channel accepts/outputs a serial stream of either NRZ or split phase

change data at bit rates up to 250 kilobits per second. The SDS has a capacity to store up to twenty 32-bit words per sample for each channel. Each sample must be preceeded by the standard IRIG SYNC word. Bulk transfer of data between the SDS and either the IBM 360 or the CDC 6600 computer is accomplished under computer control.

6.3 Future Systems

Telemetry reception over the Eglin land and water ranges is presently adequate for up to six mission participants who are above line-of-sight from the land-based TM receiving stations. Current facilities are inadequate for more than six participants or when participants descend below the line-of-site. The GTR upgrade will expand low altitude TM coverage by utilizing the AIPS as an airborne relay that will be capable of acquiring and retransmitting five TM data streams. Utilization of the AIPS as a relay is the only major change planned for the TM facilities as part of the GTR upgrade.

6.4 Telemetry Diagnostics

The radar slew diagnostic serves to verify the general process of measuring, transmitting, and receiving real-time data. However, a comprehensive TM diagnostic would ideally include transmission of data through the atmosphere under conditions approximating the mission environment. It is recommended that this be accomplished by transmission of simulated TM data from the AIPS as part of pre-test diagnostics.

7.0 COMMUNICATIONS SYSTEMS/DATA LINKS

A flexible network of wire, radio and microwave equipment makes it possible to use any part of the Eglin Land/Water Range Complex as a separate facility or to integrate the entire Complex as one vast test and development environment. A typical range/site communications configuration will have a control center with voice, control and instrumentation status circuit (wire or radio) connected to remote instrumentation sites. Portable microwave is used to extend control and data circuits to instrumentation sites in the absence of wire circuits, or to satisfy wideband data or video requirements. Fixed microwave from the Microwave Center, Building 44, on the Eglin Main Base interconnects separate range/site control centers to various control, data and communications centers on Eglin Main (see Figure 7.1).

7.1 Radio Communications

Many types of radio communication are used at test sites throughout the Eglin Complex to support missions. These include UHF air-to-ground, VHF point-to-point and air-to-ground, and HF point-to-point and air-to-ground.

Typical UHF air-to-ground radios such as the AN/GRC-171, the AN/GRT-22 and the AN/GRR-24 are used at fixed ground stations and provide the necessary channel selection and control to adequately communicate with aircraft flying in the Eglin area. Also available for close support is the AN/PRC-41, a man-pack UHF portable which will adequately cover an area of 15 miles radius.

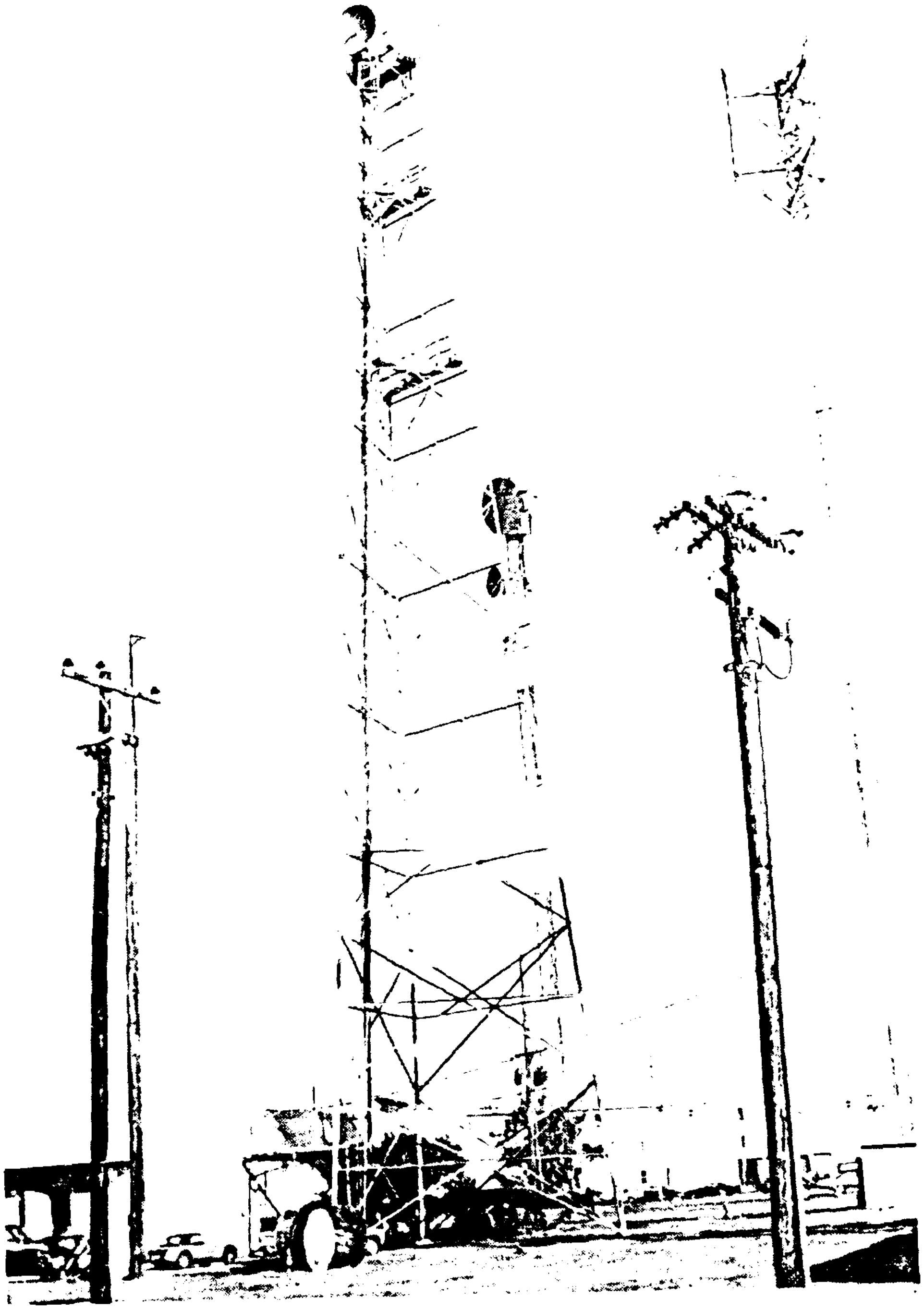


Figure 7.1 Building 44 microwave towers and antennas

UHF air-to-ground radios are located at approximately 25 sites. There are approximately 100 UHF air-to-ground systems in operation on the Eglin complex to provide communications support for over 200 test sites. Also available are modified UHF air-to-ground radios capable of transmitting secure voice.

The VHF radios are used mainly for point-to-point communications. There are two primary VHF radio nets used at Eglin. One of these nets is used for land range communications between sites and the Range Control Center on Eglin Main. This net is known as the Wolfcall Mission Control Net. The other primary radio net is used for mission support on the land ranges and is called the Explosive Ordnance Disposal (EOD) and Forestry Net. A typical combination of a VHF transmitter and receiver is the AN/GRT-21 and the AN/GRR-23. Although the major portion of air-to-ground communications is in the UHF frequencies, some aircraft still use VHF, and some of the Eglin sites are equipped to communicate air-to-ground by VHF.

The HF radios are mainly used for marine support at Eglin. Also, at times, long range communications with aircraft are supported by available HF sets. Typical HF sets available at Eglin are the KWM-2A and the RF-201 transceivers. HF radios are located at Sites A-3, D-3, A-20 and Eglin Main.

7.2 Microwave Systems

The microwave systems provide the primary path for interconnecting the EMTE Radar Sites A-20, A-3, C-10 and D-3 with Eglin Main and the land range sites through the Microwave Center. Microwave

systems branch out from Building 44 to Sites A-3, A-10, A-20, B-1, C-1 and C-10; Test Areas C-5 and C-62; and Duke Field. Building 44 has facilities to patch or bridge any combination of incoming circuits.

The microwave systems connecting Building 44 to the outlying sites are hot-standby configurations equipped with either Motorola MR-300, Collins MW-518, or Collins MW-508C microwave radios with a capacity of over 600 voice channels. Standard 3-kHz voice channels and special data channels are provided to transmit voice, data and telemetry.

The microwave system from Site A-20 to Site A-3 and Site D-3 employs Motorola MR-300 hot-standby microwave radios which provide a baseband of 8 MHz. Standard 3-kHz voice channels are provided to transmit voice, secondary data and teletype. Telemetry, radar synchronization and radar primary data channels employ specialized equipment to meet requirements. Two electromagnetic radiation (EMR) duplex 900-kHz channels are employed to relay wideband telemetry data among Site D-3 and A-3 and Eglin Main. The overland microwave propagation is in the 7-GHz frequency band.

Transportable microwave systems are utilized to provide communications for mission support at remote sites that are not near a fixed microwave system or a cable plant. The transportable system can be easily relocated to extend communication circuits from a fixed microwave system, a cable terminal, or directly from

Eglin Main. The systems employ Collins 502-D radios and a Motorola MC-30 Multiplex. Each system can provide up to 18 voice or data circuits. The systems are also capable of meeting requirements to transmit CCTV. The terminal equipment is mounted in a mobile trailer or a portable carrying case. The trailer-mounted mobile antenna can be extended to a maximum height of 110 feet if required.

7.3 Future Systems

The GTR upgrade plan calls for conversion of Eglin microwave systems from analog to digital links This conversion will allow transmission of encrypted PCM data, improve reliability and maintainability of the microwave systems, and significantly increase maximum data rates. The conversion to digital links is projected for completion by the end of calendar 1982 [3].

Additional upgrade plans call for utilization of the AIPS to relay UHF communications for aircrews flying below the line-of-sight from the range control facility.

7.4 Diagnostics

Microwave link pre-test checkout will normally be accomplished as an integral part of radar and TM diagnostics. However, after completion of the planned conversion to digital transmission, independent checks of the microwave links can be accomplished via transmission of standardized diagnostic data streams over the links to be utilized on any particular mission.

Pre-test checkout o, voice links can be accomplished through normal utilization of communication links required in the process

of preparing for the mission. Formal approaches for automated checkout of voice links do exist. For example, the Voice Interference Analysis System (VIAS) developed at the Electromagnetic Environmental Test Facility (EMETF), Fort Huachuca, AZ, is used for fast automatic determination of voice intelligibility for analog links. However, based on the past history of Eglin missions, it does not appear that the use of a sophisticated checkout system such as VIAS is warranted.

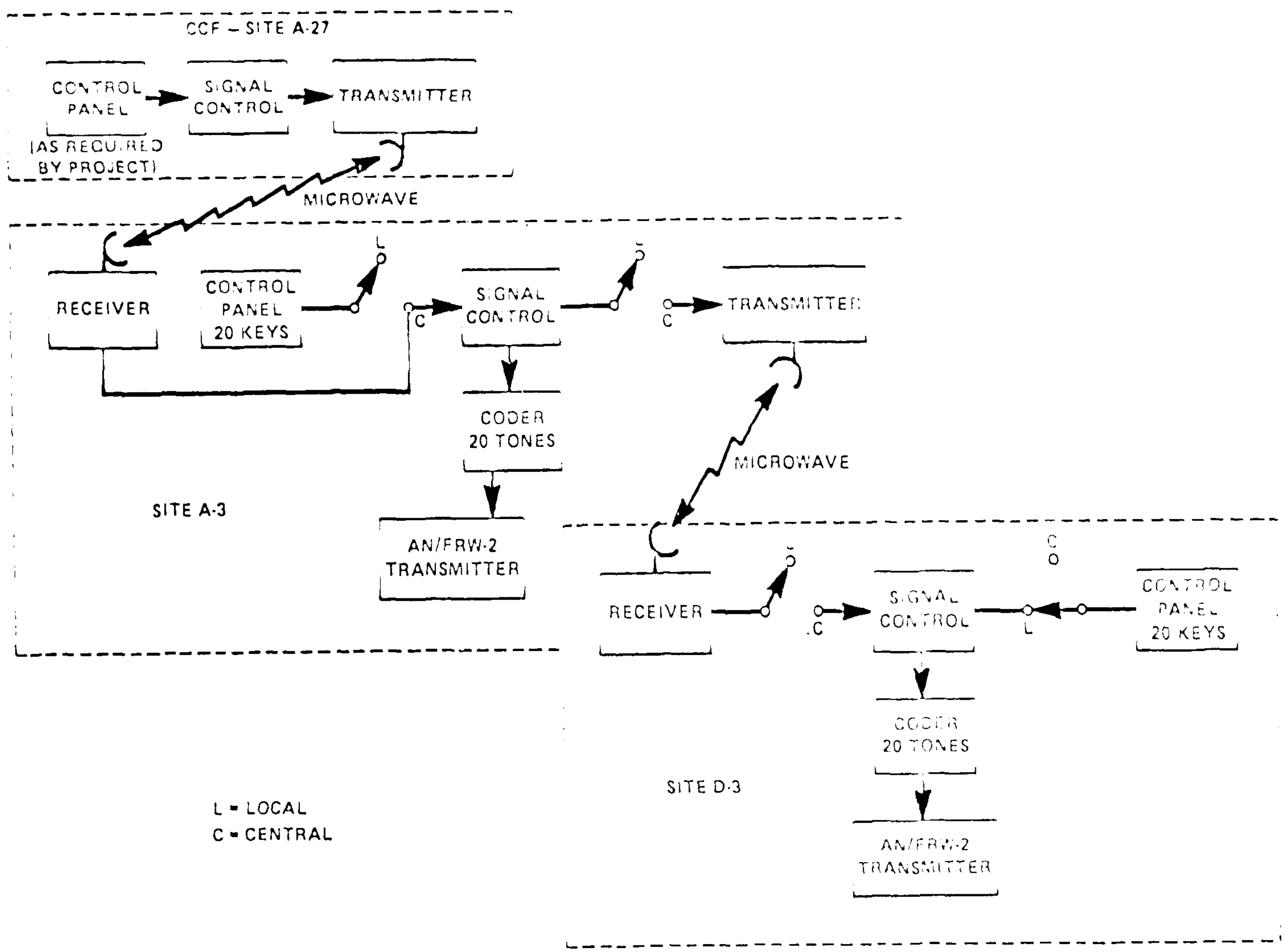
8.0 COMMAND/CONTROL AND FLIGHT TERMINATION SYSTEMS

8.1 Command-Guidance System

The command and control function for the Eglin range is provided by a UHF command-guidance system (Figure 8.1) which provides the command link for remotely controlling unmanned airborne systems such as drones and missiles from ground stations. The primary command-guidance capability employs AN/FRW-2 UHF radio transmitters. Radar beacon control can also be exercised through the G (C)-band and E(S)-band radar sets. The Bomarc ground-to-air transmitter (GAT), although primarily used for Bomarc interceptor command guidance, is integrated with the range safety circuits for the destruct function.

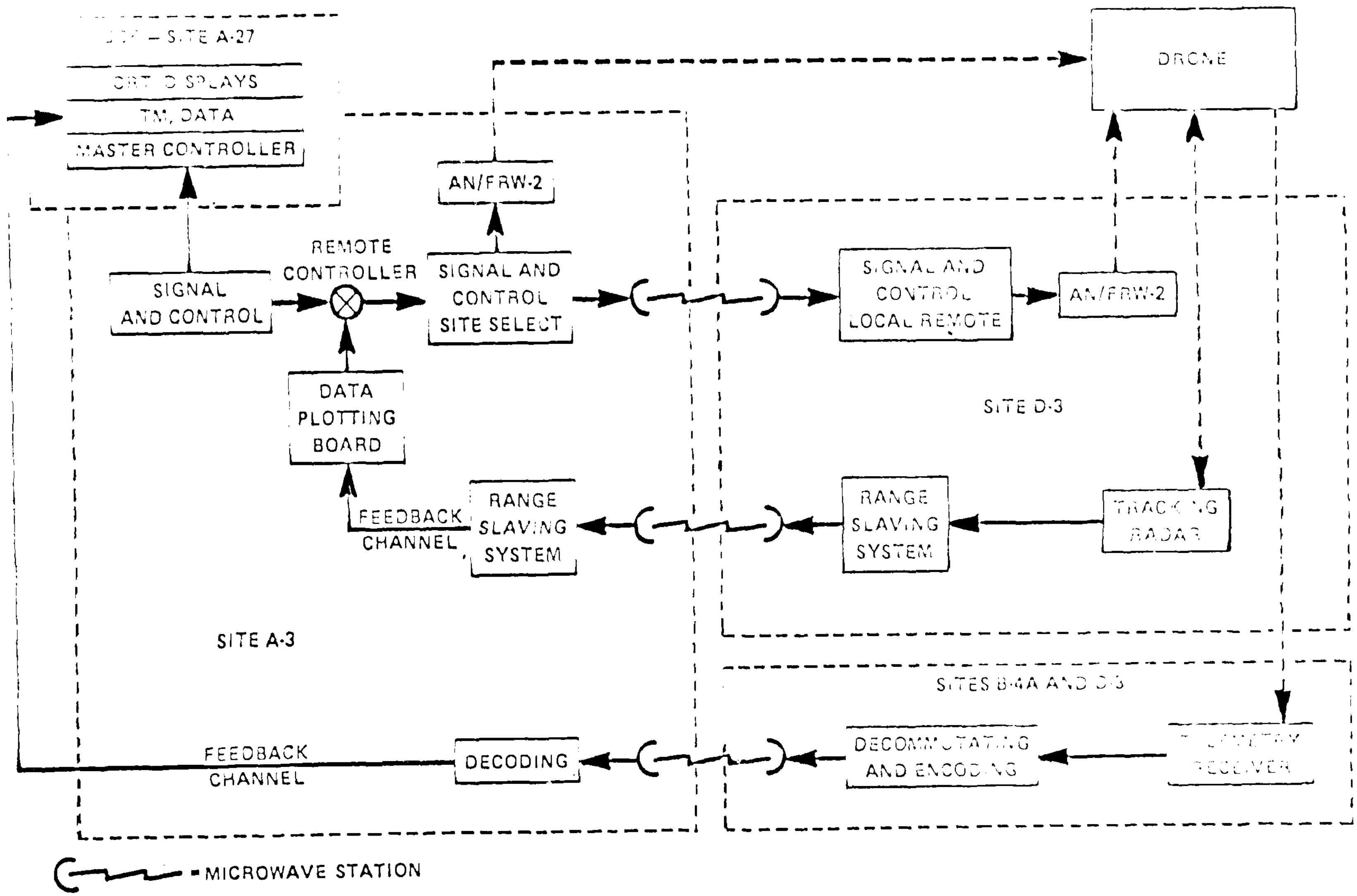
The UHF command-guidance radio transmitters are operated in conjunction with the signal and control (S&C), communications, radar, data, and telemetry systems to control the flightpaths of drones or missiles. The S&C system is used for remotely controlling remote test site transmitters from Site A-27 (Figure 8.2) The communication system passes secondary and telemetry data uprange in real-time, transmits control signals downrange, and provides voice communication among the operating personnel. The radar, data and telemetry systems feed back position and other quantitative information to the controller.

There are two UHF command-guidance chains in parallel extending from Site A-3 through Site D-3. In chain operation, the source of the UHF command transmission is passed from site



Block Diagram of Command-Guidance System

Figure 8.1



Block Diagram of Remote Control Systems

Figure 8.2

to site with the progress of the mission. The two chains can operate independently to control two unmanned systems simultaneously, or one chain can be used as backup. The UHF command-guidance system has been primarily employed to position drones; however, with the availability of lightweight receiver equipment, it is adaptable to effect remote control of a wide variety of systems in which automatic control equipment can be installed. The same line-of-sight restrictions apply to the UHF command-guidance coverage as apply to the radar sets. With the AN/FRW-2 directional antenna, this coverage is extended over that of an omnidirectional antenna.

8.2 Signal and Control (S&C) System

Certain key individuals, such as the Test Director, Range Safety Officer and Range Chief, must process a large amount of mission information. The time required to receive and interpret this information and issue directions by voice is too lengthy to effect adequate control of various mission functions. The purposes of the S&C system are:

- To provide visual displays of status information.
- To effect remote control, thereby alleviating the problems resulting from total dependence on voice communications.

Visual displays, properly grouped for ease of interpretation, convey a large quantity of status information. Attention is attracted to problem areas by red lights; ready

status is indicated by green lights; and confirmation lights signify the completion of control functions. The S&C system accomplishes a partial automation of the mission control operation by supplementing voice communications. In many instances, the system appreciably reduces the time response of the closed-loop control process, thereby allowing key personnel to concentrate on mission control functions.

The S&C system frequency shift keying with the transmission of one-tone frequency indicating a mark signal and the transmission of another frequency indicating a space signal. A maximum of 23 signals, using a frequency division multiplex system, can be transmitted simultaneously on one voice channel, with the two conditions of information reversible up to 40 Hz (25 millisecond response time). With time division multiplexing, as many as 32 signals may be transmitted over one frequency division channel. Figure 8.3 shows typical signal and control circuits. A third alternative to the two circuits shown in a "secure" circuit, employing a coder and decoder for the destruct function.

The S&C system is readily adaptable to the transmission of any two-condition function such as MARK/SPACE switching, GO/NO GO control, and READY/HOLD status. Some of the important functions handled by the signal and control system are as follows:

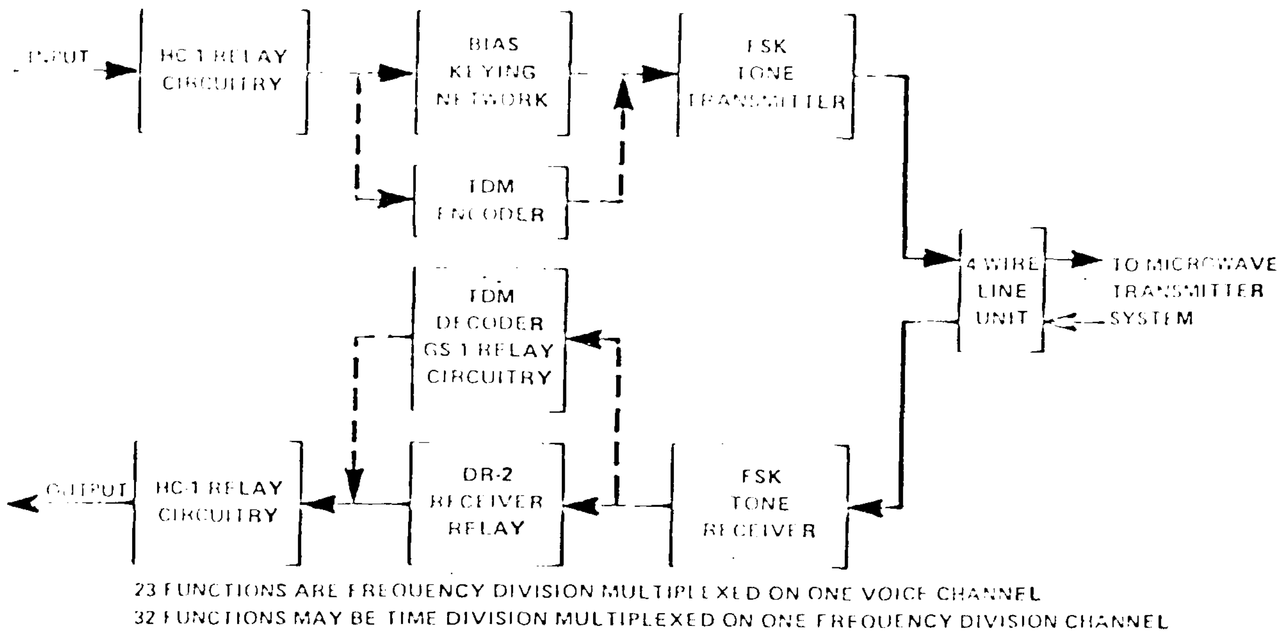
- Site select and confirmation

  Command source, missile and drone

- Mode select and confirmation

  Missile radar, GAT or UHF mode

  Drone radar or UHF mode



Block Diagram of Typical S&C Circuit

Figure 8.3

- Destruct and confirmation, missile and drone
- Command guidance, missile and drone
- Status reporting, missile and drone
- Holdfire, missile and drone
- Range control (central-local), missile and drone
- Command control lockouts

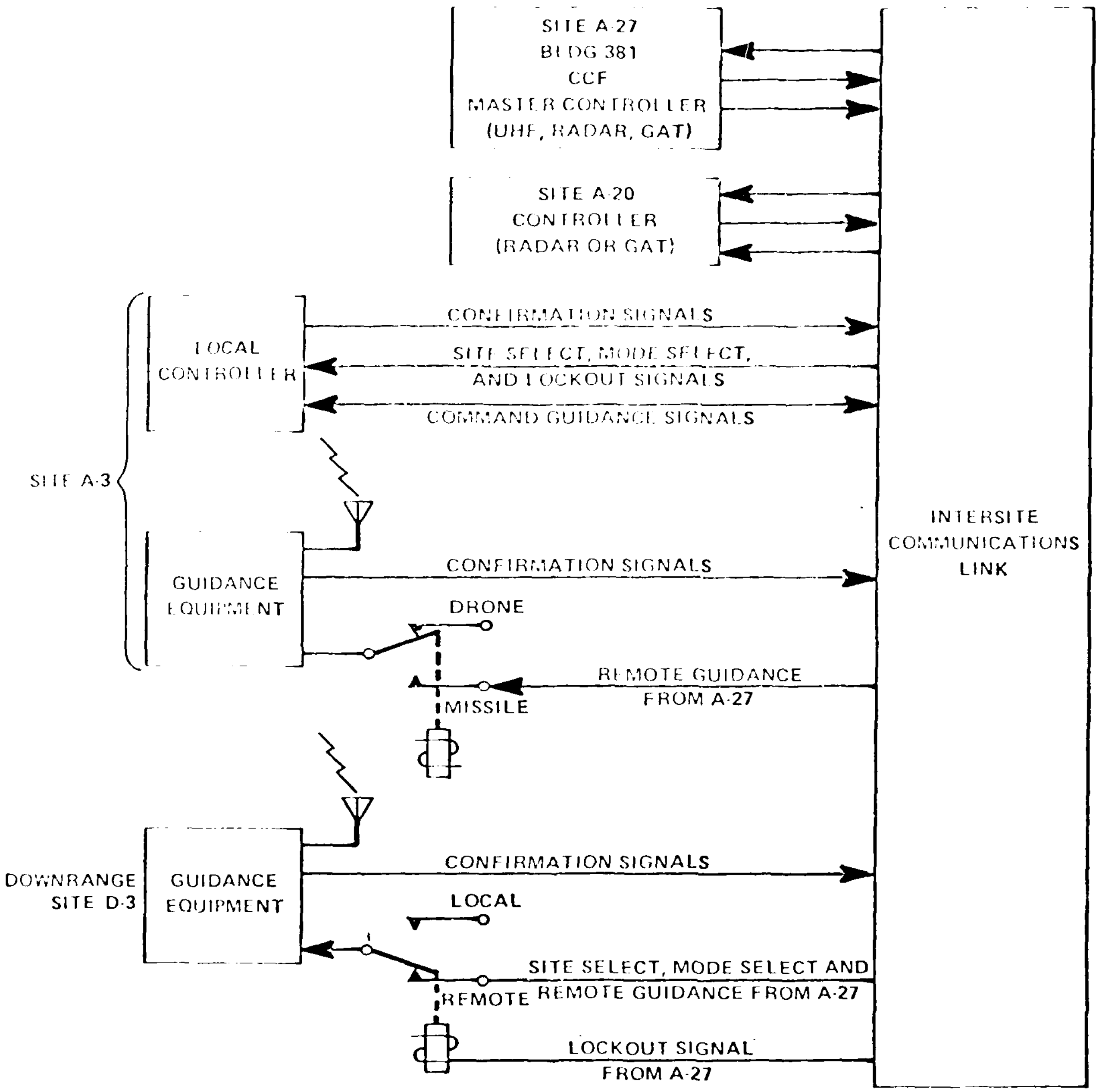
  Missile and drone, command guidance, and destruct

  Skyscreen destruct

8.3 Destruct System

Command destruct tones can be transmitted by the AN/FRW-2 transmitters or, for Bomarc tests, through the GAT system. As backup on Bomarc tests, coded destruct signals can also be transmitted by the FPS-16 radars. The S&C system is the means of integrating various types of equipment at widely dispersed sites into a system allowing some degree of operation flexibility and, in the case of AN/FRW-2 utilization for the destruct function, providing simultaneous or alternate routing of the destruct signal.

Site A-3, or Building 381 (CCF, Site A-27) can exercise control of the command source transmitters, or relinquish control to the local sites by means of the central/local mode switch. In the central mode of operation, the command source site is selected remotely, determining the site at which the radar or UHF coder are keyed on the ground-to-air transmitters (Figure 8.4). In the local mode of operation, the lockouts on all sites are simultaneously removed, and the decision to transfer control from one site to another is reached by voice communications.



Command Guidance, Site Select and Mode Select

Figure 8.4

The selection of a site turns on the carrier of the UHF transmitter. The selection of a mode enables the radar and/or the UHF coders for command guidance and destruct. Selection of either one or more sites for the destruct command is possible.

8.4 Future Systems

The GTR upgrade calls for the introduction of an MLS drone control system to satisfy future air-to-air (A-A) requirements. Air-to-surface (A-S) safety and mission requirements will be satisfied by the Multiobject Tracking, Ranging and Control System (MTRACS) which will provide remote control of up to ten land targets such as tanks or trucks. The MTRACS, which is a very sophisticated MLS, is currently under development. A flight termination system (FTS) is required for all drones and for many A-A and A-S munitions. As outlined aboved, the current FTS utilizes FRW-2 command and control equipment which is an aging system operating on an unprotected frequency. The future FTS projected for the GTR upgrade will utilize MLS techniques.

As discussed in Section 4.4.1, an MLS transponder will be carried aboard all drones and missiles for purposes of A-A TSPI coverage. Both the drone control and TSPI functions will be accomplished by means of an integrated drone MLS system. The same MLS transponder used for drone control will be qualified for use as a FTS communication link. Likewise, the MLS transponder for missile TSPI will be used for missile flight termination.

The MLS transponders, which are currently under development and should be available in FY83, will provide frequency protected flight termination capability.

The objectives of the MTRACS system include provisions for tracking and selective flight termination of at least 12 missiles inflight, as well as tracking and control of land targets and tracking of the launch aircraft. The MLS "hockey puck" missile transponder under development by AD will be used for MTRACS flight termination.

8.5 Diagnostics

As outlined above, substantial changes in Command/Control (C^2) and FTS systems are planned for the Eglin range. Future systems will utilize MLS techniques, as will future range tracking systems.

The MLS FTS data link to drones and missiles will include four uplink commands: Off, Prearm, Arm and Fire. Five downlink signals will provide status of the four command states and, additionally, the destruct battery voltage. Drone and missile FTS systems will respond only to unique address codes so that selective flight termination will be possible.

A comprehensive pre-test checkout of C^2 systems, and in particular the FTS system, is clearly of critical importance to the range safety control function. However, the transition from current systems to MLS techniques will give rise to significant changes in pre-test diagnostic methodology. It is recommended

that a study be conducted to establish requirements for pre-test checkout of the new C^2 and FTS systems.

9.0 SUMMARY

A comprehensive review of all major elements of the Eglin range safety control system has been conducted. Recommendations have been made for pre-test diagnostics of these elements. A further review of projected range instrumentation systems that will be introduced on the Eglin range in conjunction with the GTR upgrade has also been accomplished. Where possible, recommendations related to checkout of these new systems have been developed. In other cases, recommendations for required future study have been made.

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STATEMENT OF WORK

The effective range safety control of an AD weapon test requires that systems used for control (e.g., radars, telemetry, communications, data links, computers) be functioning properly and be fully prepared for their test responsibilities. Malfunctioning or unprepared systems can cause test cancellations, lengthy test delays or erroneous flight termination decisions by the RDO. A review and update of current CCF CDC 6600 pre-test range safety systems, diagnostic procedures and criteria is needed in order to ensure that the possibilities for such cancellations, delays and unneeded flight terminations are reduced to a minimum.

The contractor is directed to review all CCF CDC 6600 pre-test diagnostic procedures and criteria currently used for systems required for the range safety control of AD weapon tests and to develop and recommend improved procedures and criteria, if needed. The study should involve the following steps:

1. Review all CCF CDC 6600 pre-test procedures and criteria currently used for the pre-test diagnostics of systems used for the range safety control of AD weapon tests. Systems reviewed should include:
   a) Tracking systems
   b) Communication systems
   c) Telemetry systems
   d) Data links
   e) Computer systems

f) Display systems

g) Flight termination systems

h) Command/control systems

2. Identify deficiencies in the current pre-test diagnostic procedures and criteria.

3. Develop and recommend new CCF CDC 6600 procedures and criteria required to resolve the current deficiencies. The recommended procedures and criteria should be included in an overall plan for the pre-test range safety diagnostics for each type of AD weapon test, including:

a) Air-to-ground

b) Air-to-air

c) Tail warning sets

d) High altitude probes

The plans should include clear step-by-step descriptions, with flowcharts, of pre-test procedures for each type of test.

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